Oregon State University

Agricultural Experiment Station

Synthesis of Knowledge on the Effects of Fire and Thinning Treatments on Understory Vegetation in U.S. Dry Forests

Anne M. Bartuszevige and Patricia L. Kennedy

A SUMMARY OF KNOWLEDGE FROM THE Joint Fire Science Program

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Synthesis of Knowledge on the Effects of Fire and Thinning Treatments on Understory Vegetation in U.S. Dry Forests

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Cover photos: Top: A feller at the Blue Mountain Fire and Fire Surrogate site in northeastern Oregon. (Elizabeth Dodson Coulter) Bottom: A squad leader uses a drip torch to clean up a fire line on the Bear Prescribed Fire in Washington. (Cason McCain, USDA Forest Service, fs.fed.us)

Contents

SUMMARY 5
INTRODUCTION 7
Importance of understory herbaceous plant communities in U.S. dry forests *11*
GOALS, SCOPE, & ORGANIZATION OF THIS DOCUMENT 12
METHODS 14
Scoping meetings *14*
Literature search and criteria for inclusion *14*
RESULTS 15
Inland Pacific Northwest *15*
Rocky Mountains *20*
Sierra Nevada *23*
Southeastern United States *24*
Eastern Deciduous Forest *26*
Effects of fire on rare, threatened, or endangered plants *28*
DISCUSSION 30
Intensity, frequency, and season of disturbance *30*
Seed sources *32*
Time since disturbance *32*
Rare, threatened, and endangered species *33*
CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS 33
REFERENCES 35

TABLES 39
Table 1 ..... *39*
Table 2 ..... *42*
Table 3 ..... *45*
Table 4 ..... *52*
Table 5 ..... *64*
Table 6 ..... *98*
Table 7 ..... *100*
Table 8 ..... *101*
Table 9 ..... *102*
Table 10 ..... *106*
Table 11 ..... *109*
Table 12 ..... *119*
Table 13 ..... *122*
Table 14 ..... *123*
Table 15 ..... *124*
APPENDIX 1. SPECIES INCLUDED IN THIS SYNTHESIS 128
APPENDIX 2. KEYWORDS USED TO SELECT LITERATURE FOR INCLUSION 132

A squad leader uses a drip torch to clean up a fire line on the Bear Prescribed Fire in Washington. (Cason McCain, USDA Forest Service, fs.fed.us)

SUMMARY

A century of fire exclusion in dry forests across the United States has resulted in high fuel loads and increasing dominance by fire-intolerant vegetation. Federal, state, and private agencies have adopted a goal of managing forests to reduce the risk of high-severity wildfire. Forest managers use a variety of tools to create desired conditions within forests; the most common are prescribed fire and mechanical thinning. These two treatments may be used separately or in combination, depending on restoration goals for the forest stand. Before these treatments can be applied, managers must justify their choice by documenting the effects of the treatment on other ecosystem components, such as understory vegetation. Understory vegetation in fire-dominated landscapes often has adapted to regrowing in frequent, low-severity fire regimes. Because fire releases nutrients and, by opening the canopy, allows light to the forest floor, the understory response is positive (e.g., increased growth or reproduction).

Scientific reviews of the literature document the effect of fire (prescribed and wildfire) on both native and exotic understory vegetation. However, no synthesis is available on the effects of thinning treatments on understory vegetation. One goal of this document is to synthesize the literature on the effects of mechanical thinning on understory plant

species. A second goal is to document the effect of prescribed burning on rare, threatened, or endangered species. We review current literature on studies that address effects of prescribed fire and thinning treatments on understory vegetation. The studies' outcomes are presented in two sets of tables: (1) functional group results, and (2) species-specific results. Managers often are interested in and need to report the effects of treatments on species; functional group responses can provide a clue to how a species might respond if no other information is available.

In general, fire and thinning treatments increased response of understory species. More intense treatments, such as combined thin+burn treatments and greater thinning intensity, had the highest increases in cover and production. Thin-only and burn-only treatments had more moderate increases. In addition, most studies found exotic plants' response increased as disturbance intensity increased; however, most studies report very low invasive presence even after the treatments. If one of the goals of the forest management plan is to increase presence or cover of understory species in general, then prescribed fire and thinning treatments may be a viable option to restore forest understory.

Rare, threatened, and endangered species in dry forest environments often respond favorably to prescribed fires. Many of the species reported in this document increased in abundance or reproduction or were unaffected by fire, indicating that prescribed fire is compatible with (or beneficial for) restoration of these species.

The results of this synthesis illustrate several important lessons. First, current forest structure is the result of decades of fire-suppression activities, and so restoration will require multiple treatments to bring forests to within the range of historic variation.

Second, while the treatments discussed in this document generally increased native plant responses, the same treatments also increased exotic plant response. Therefore, to avoid spread of exotic plant species, it is important to consider the context of the treatment area, (e.g., nearby roads, wildland urban interface, previous exotic plant invasions) before applying the treatments.

Third, applying thinning and prescribed burning treatments in a mosaic pattern of treatment time and type across the landscape will help to maintain a diversity of vegetation (e.g., early-, mid-, and late-successional species across the landscape).

INTRODUCTION

Most North American forest plant species evolved under the influence of fire and, consequently, many ecological processes in these forests are fire adapted. However, for much of the 20th century, land managers concentrated on minimizing the amount of land that burned. Compared to presettlement *fire regimes* in many contemporary forests, fire intervals have greatly lengthened. (Fire regimes are the patterns of fire occurrence, size, and severity—and, sometimes, vegetation and fire effects as well—in a given area or ecosystem.) Increased recognition of the central role of fire in maintaining forest structure and function has contributed to a shift from fire exclusion to the reintroduction of fire in fire-dependent forests. This recognition has prompted federal initiatives such as the National Fire Plan and Healthy Forest Restoration Act (2003) which mandates federal land managers to restore forest structure and function and to reduce risk of wildfire on federal lands (Graham et al. 2004; Schoennagel et al. 2004); see figure 1. It is now widely accepted that the return of fire to dry forests restores ecological processes, creates ecologically valuable early successional habitats, and is consistent with management objectives aimed at maintenance of biodiversity and decreased risk of landscape-scale wildfires (Brawn et al. 2001; Fulé et al. 2004). However, how and if the process of fire is reintroduced is less certain, particularly since fire-suppressed forests have developed dramatically different structures than when fire was more frequent (Covington and Moore 1994; Van Lear et al. 2005). Lack of fire has also increased fuel loads in many western forests which has increased the probability of large, high-severity wildfires (Schoennagel et al. 2004); see figure 1.

Figure 1. Cerro Grande wildfire as it approached Los Alamos, NM, in 2000. This fire started as a prescribed burn, but weather and forest fuel conditions allowed the fire to enter the forest canopy and become a large (>17,000 ha [>42,000 acres]), high-severity fire that threatened Los Alamos National Laboratory and burned 235 homes. (Rick Wilking, Reuters)

The goal of prescribed fire is to reduce surface fuels and to thin small understory trees and saplings to reduce ladder fuels (Graham et al. 2004); see figure 2. In most areas, historical wildfires were ignited by lightning, late in summer when fuels were dry and fire could carry across the ground surface (figure 3). But because many forests have high fuel loads compared to historical conditions, prescribed burning during the "typical" fire season

Figure 2. A prescribed fire in the Gallatin National Forest, Montana. (USDA Forest Service, fs.fed.us)

Figure 3. Lightning is a common ignition source for wildfires. (Susan Strom, lightninglady.com)

is a risk many managers and the public are unwilling to take. Therefore, prescribed fires are often set in early spring or late fall, when cooler temperatures, higher humidity, and moister conditions are the norm. Prescribed fires set at this time result in a lower intensity treatment. The success of the prescribed fire is determined by weather conditions and is therefore unpredictable (Graham et al. 2004). Thus, fire managers may employ mechanical thinning techniques which yield a more predictable result.

Mechanical thinning treatments can be precisely applied to make progress toward a desired forest structure (figures 4a–b). In general, mechanical thinning removes trees that act as ladder fuels; however, surface fuels are not necessarily reduced by mechanical thinning alone (Graham et al. 2004). Thinning alone and burning alone address separate forest structural conditions: thinning addresses vertical fuels, and burning addresses surface fuels. However, in many cases a combination of thinning and burning is required to reduce fuels and properly address restoration of forest structure.

There are several methods of mechanical thinning. *Understory thinning* (also called low thinning, or thinning from below) removes small trees from below the upper canopy layers; the smaller trees can act as ladder fuels for fires to move into the canopy (figure 5). In drier, pine-dominated forests, low thinning typically favors fire-tolerant ponderosa pine, which is found in the upper canopy, and it removes fire-intolerant species such as grand fir, white fir, or Douglas-fir (Graham et al. 1999). Thinning pre-scriptions commonly specify a reserve basal area target, a diameter limit (expressed as diameter at breast height [DBH; about 4.5 feet above ground level]) above which all trees are retained, or a percentile size target (e.g., all trees above the 25th percentile are retained; Brown et al. 2004). The trees removed under these thinning prescriptions are typically small to medium size; they may not have commercial value, depending on location and proximity to wood-processing facilities or

Figures 4a–b. Mechanical thinning operations. At left, a harvester performs a mechanical thinning operation in the Northern Rockies. (Andrew Youngblood, USDA Forest Service, cfc.umt.edu) At right, a forwarder works at the Blue Mountain FFS site in northeast Oregon. (Elizabeth Dodson Coulter)

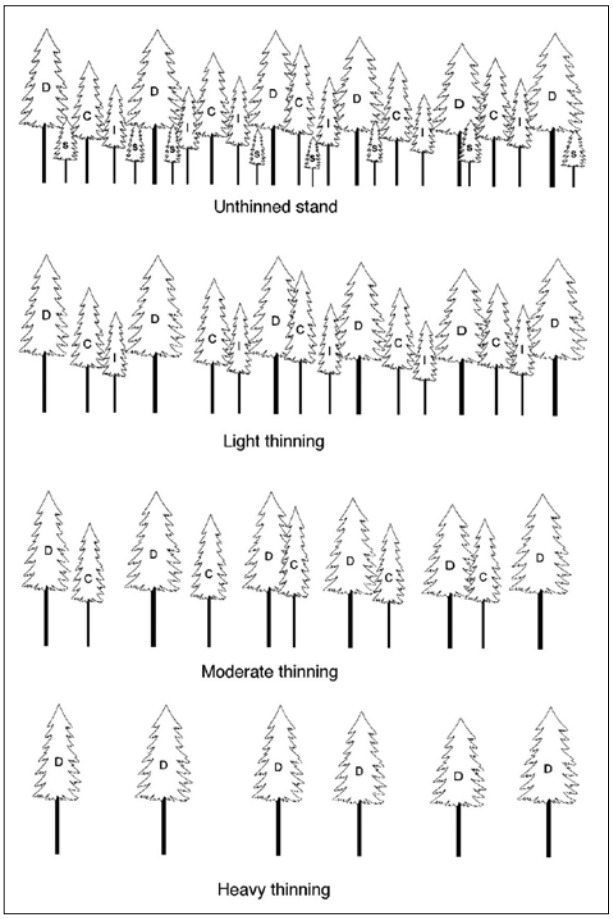


Figure 5. A 120-year-old conifer stand containing a mixture of dominant (D), codominant (C), intermediate (I), and suppressed (S) trees thinned from below (understory or low thinning) to three different stand densities. (Graham et al. 1999)

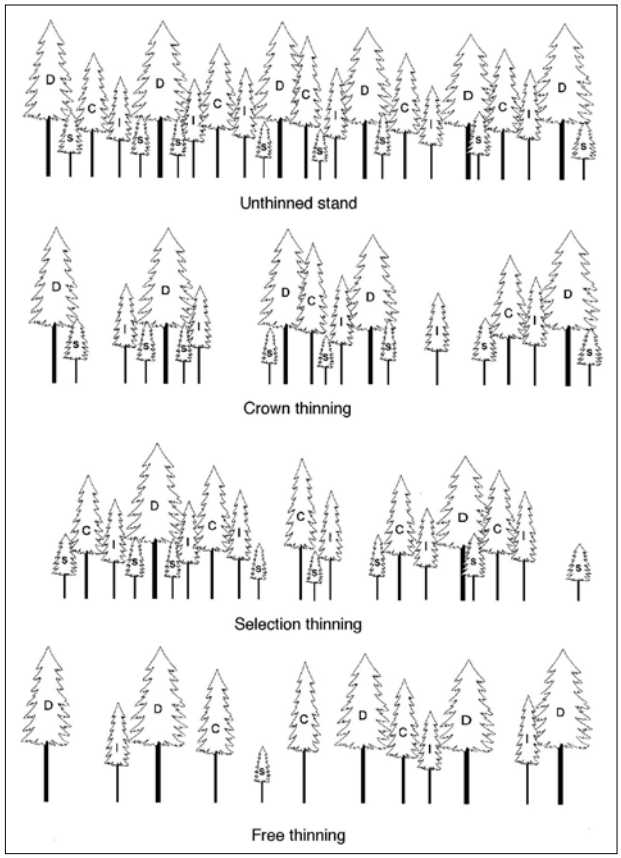


Figure 6. A 120-year-old conifer stand containing a mixture of dominant (D), codominant (C), intermediate (I), and suppressed (S) trees receiving a crown, selection, or free thinning. (Graham et al. 1999)

cogeneration plants. Slash may be removed from the site or left in the woods and dispersed, burned, or masticated, but it still may increase fuel loads (Brown et al. 2004).

Overstory thinning (also called crown thinning or thinning from above) removes older, larger trees to thin the forest canopy, aiming to prevent fires from spreading through the canopy should they reach it. This type of thinning maintains vertical structure in the forest, which can benefit wildlife (Graham et al. 1999). In addition, the larger trees removed can provide some financial return. Overstory thinning can be accomplished in any of several ways. *Selection thinning* removes large, commercially valuable trees from the forest, to allow trees in the lower canopy to mature (Graham et al. 1999); see figure 6. *Free thinning* removes trees around target individuals chosen based on treatment goals such as maintaining certain tree spacing (Graham et al. 1999); see figure 6. *Mechanical thinning* removes trees in a specified spatial pattern, such as every other row in a plantation (Graham et al. 1999).

Fire is a unique ecosystem disturbance that restructures habitat and soils that many plants depend on for germination and growth. The extent to which thinning approximates the effects of prescribed-fire responses in forested ecosystems is not well understood; however, thinning may approximate fire for certain ecosystem attributes. It is important to understand:

Figures 7a–b. Fire releases nutrients that become available to resprouting plants. At left, a longleaf pine sprouts from the base of a fire-damaged seedling. (USDA Forest Service, Bugwood.org) At right, a spring flower is regenerating from underground rootstock after the Ham Lake Fire, in Minnesota. (Bob Kelleher, Minnesota Public Radio News, Duluth, MN)

(1) how thinning approximates fire over time, and (2) the thinning intensities needed to achieve different ecosystem properties and management goals (e.g., biodiversity, nutrient cycling, and reducing fire hazard). The degree to which thinning or prescribed fire can be used to restore ecosystem structure in forests that have experienced a century of fire exclusion is unclear.

Fire releases nutrients, making them available to germinating and resprouting plants (Boerner et al. 2006; Bond and van Wilgen 1996; Lione 2002; Gundale et al. 2005, 2006). Fire also removes litter and opens the canopy, letting more light reach the forest floor. The increased light creates higher temperatures at the forest floor, which may stimulate seed germination (reviewed in Whigham 2004). The reduction of litter also exposes bare mineral soil which provides an area for seeds to germinate. Many plants in fire-prone systems are adapted to take advantage of this short-term release of nutrients; as a result, growth after fire is faster and more lush than at other times (Bond and van Wilgen 1996); see figures 7a–b and figure 8.

Figure 8. Understory vegetation growth two years after the Biscuit Fire in southwest Oregon. (Joseph B. Fontaine)

Thinning is a disturbance that removes vegetation from the forest instead of consuming vegetation. The result of removing vegetation is that unless slash is left on site, nutrients stored in the vegetation are lost to the system. As a result, influxes of nutrients in thinned forests may be lower and different in composition than in burned forests. In a loblolly–shortleaf pine forest (scientific names are found in appendix 1), thinning increased potassium and magnesium, fire decreased carbon and nitrogen in the organic horizon, and both treatments increased soil pH (Lione 2002). In a mixed oak forest, thinning reduced soil carbon in the first year after treatment; in contrast, in burned areas, a reduction in soil carbon was not detected for several years after treatment (Boerner et al. 2006). Like burning, thinning increases bare mineral soil (Boerner et al. 2007). By thinning the canopy, light is increased at the forest floor, which can increase surface temperatures. The additional bare mineral soil and light can provide areas for seeds to germinate and establish as seedlings; however, this effect may be true only if slash is removed.

Importance of understory herbaceous plant communities in U.S. dry forests

Early forest management emphasized recruiting trees for commercial harvest. Understory vegetation competes with and inhibits the growth of desirable tree species (Glover et al. 1989). However, in the last half of the 20th century, forest management practices have shifted focus to manage for ecosystem properties, not just for high-quality timber. Included in the idea of ecosystem health is managing for biodiversity. In most forests, the majority of plant biodiversity is found in the understory herbaceous layer (figure 9). Gilliam (2007) calculated the biodiversity of a variety of forests (e.g., black spruce, longleaf pine, mixed hardwood, mixed conifer, northern hardwood, oak barren, and white spruce) as a ratio between the diversity of herbaceous plants to trees. He found, on average, six herbaceous plant species for every tree species. In other words, 80% of the plant diversity in forested ecosystems is contained within the herbaceous strata. The diversity in the herbaceous layer is even more exaggerated in longleaf pine ecosystems of the Southeast. Gilliam (2007) also calculated a ratio of 251 herbaceous plants to one tree in this ecosystem.

In addition to harboring high diversity, understory herbaceous communities have profound effects on forest nutrient cycling. Understory plant vegetation has high amounts of important nutrients, and litter from senescent understory herbs degrades faster than leaves from trees. As a result, nutrient cycling in forests with a well-developed herbaceous understory is faster and made available to tree species more quickly than those nutrients held in woody species with little herbaceous understory (reviewed by Gilliam 2007).

Despite the potential benefits of understory plants to increased nutrient cycling in the forest ecosystem, the herbaceous plant community does compete with young tree seedlings. Understory plants can take up more nutrients than tree seedlings (Lyon and Sharpe 2003). Understory plants that are tall or have broad leaves can block sunlight from reaching tree seedlings (Horsley 1993). George and Bazzaz (2003) found that understory plants could inhibit the growth of several different species of tree seedlings. In extreme situations, understory plants can alter or halt forest succession by forming dense understory canopy layers that block sunlight for tree seedlings (Royo and Carson 2006).

Figure 9. Understory plants contribute the majority of species diversity in forested ecosystems. (Dave Powell, USDA Forest Service, Bugwood.org)

GOALS, SCOPE, & ORGANIZATION OF THIS DOCUMENT

The effects of fire on understory plant species has been thoroughly reviewed in two documents: (1) Brown and Smith (2000) edited a comprehensive volume on the effects of fire on native flora; and (2) Zouhar et al. (2008) edited an additional volume on the effects of fire on invasive plant species.

Also, the Fire Effects Information System (www.fs.fed.us/database/feis) provides detailed qualitative descriptions of fire effects on a multitude of plant species. However, very little information is available on the effects of thinning treatments on understory plant species. In addition, none of the fuels-reduction reviews incorporates the recently published experimental literature generated from the Fire and Fire Surrogate (FFS) program (see sidebar and figure 10). Understory herbaceous plant investigations (on both native and exotic species) have been conducted at almost all FFS sites (Youngblood et al. 2007), and publications are being generated from each site. Few syntheses of FFS results have been published, with the exception of papers by Stephens et al. (2009) and Schwilk et al. (2009).

Fire and Fire Surrogate (FFS) program

The FFS program is an integrated national network of long-term studies established to document consequences of using low-severity prescribed fire and thinning treatments for fuel reduction and forest restoration. The FFS study network is the largest operational-scale experiment ever funded to test silvicultural and prescribed fire restoration treatments, and thus is crucial to understanding the responses of understory vegetation to fire management strategies. The FFS was initiated in 1999 and currently includes 12 sites on federal- and state-administered lands extending from the Cascade Range in Washington to south Florida (figure 10). These 12 sites represent ecosystems with frequent, low- to mixed-severity natural fire regimes. At each site, a common experimental design was used to facilitate broad comparisons of treatment effects on a wide variety of variables (approximately 400).

This document aims to make the literature on understory plant response to thinning accessible to forest managers who design and implement hazard reduction or restoration projects. In addition, we included an analysis of prescribed fire when it was included as a treatment comparison with a thinning treatment (e.g., the FFS studies).

A secondary goal is to provide a document that complements previous reviews (Brown and Smith 2000; Zouhar et al. 2008) and helps to fill in knowledge gaps. We approached this project as an opportunity to give land managers a resource that would allow them to rapidly look up species- and community-level information on disturbance response and associated natural history. Community-level information is presented as the response of broad functional groups (e.g., graminoids, forbs) to treatments. We attempted to include as much of the peer-reviewed scientific literature as possible in summary tables for dry forests of the United States.

Managers should be able to use this document to determine the following:

1. Whether information exists on the response of species in the project area to the proposed treatment(s);
2. For species with information, whether there is a consistent response to a treatment (positive, negative, or no response); and
3. For species with no information, whether the response of its associated functional group(s) could be used to predict species-level responses.

By including literature that specifically addresses prescribed fire and thinning effects and by emphasizing studies that compare effects of both prescribed fire and thinning treatments, managers can begin to evaluate how understory vegetation responds to various treatments.

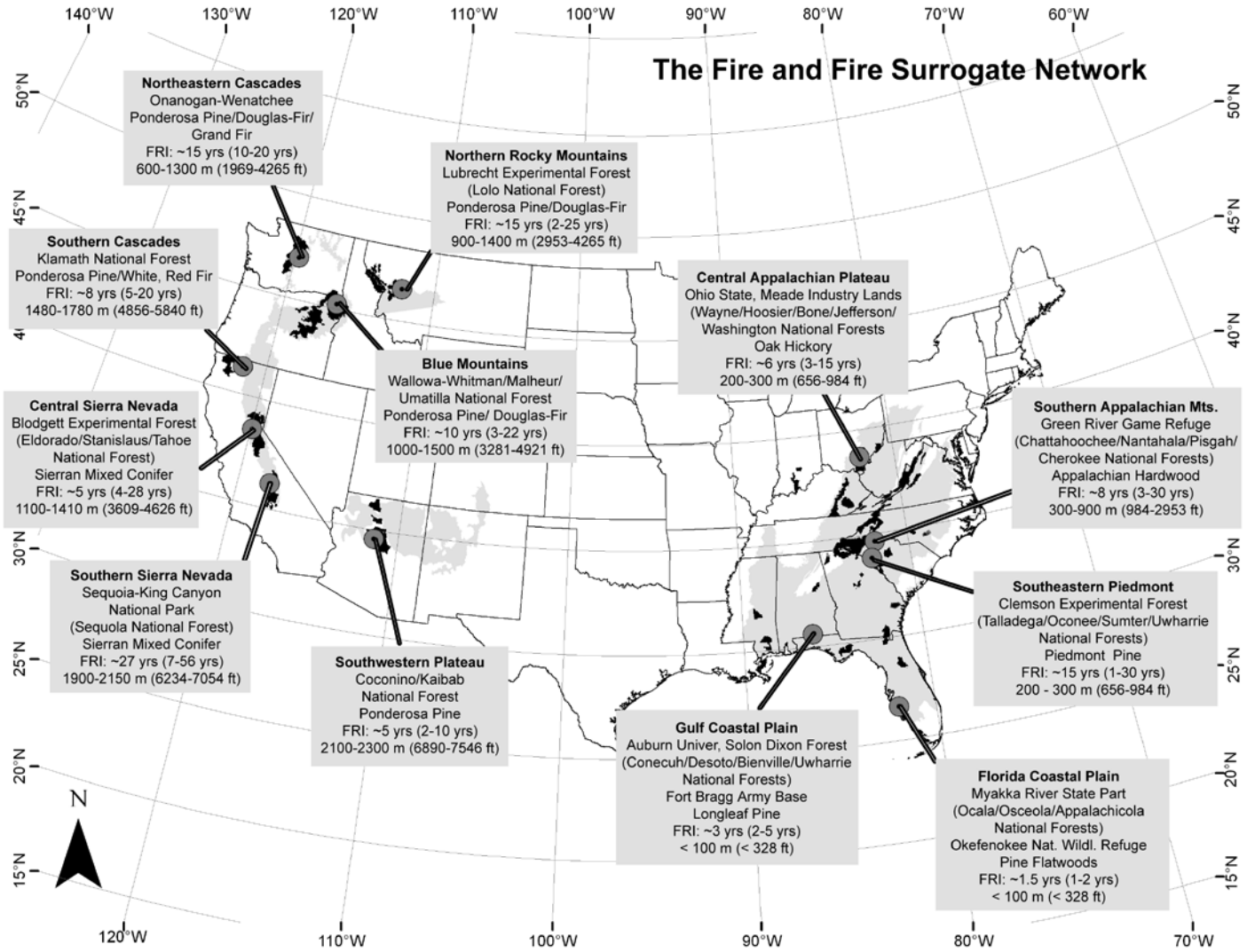


Figure 10. Names and locations of 12 fire and fire surrogate (FFS) sites, showing nearest federal lands, fire-return interval (FRI), and elevational range. The black-shaded areas indicate adjacent federal lands. Other shaded areas indicate representative land base or the area to which FFS results can be most directly applied for each site. Representative land bases are derived from EPA Type III Ecoregions (www.epa.gov/wed/pages/ecoregions/level_iii.htm). (McIver et al. 2008)

We divided this document into regions, and within each region we discuss the relevant literature and provide a bibliography of relevant literature for further details. While fire affects many types of ecosystems, we discuss only effects of fire and thinning as they relate to dry forests across the continental United States (mesic forests and shrublands were beyond the scope of this document). In addition, we focus our attention specifically on the effects of thinning on understory vegetation. Prescribed fire is included in this document as a comparison to thinning treatments and its effect on threatened and endangered species in dry forested regions.

METHODS

Scoping meetings

A one-day meeting with federal agency personnel was held in Boise, Idaho, in the fall of 2007. Attendees represented the USDA Forest Service and U.S. Bureau of Land Management from all regions included in this document. Meetings focused on identifying knowledge gaps, specific needs, and useful content and organization. The consensus of the workshop attendees was to develop a document that provided tabular summaries of the literature organized by region.

Literature search and criteria for inclusion

In December 2007 and again in July 2008, we performed a search of the scientific literature investigating fire and thinning treatments. Appendix 2 is a detailed list of the keywords used in the literature search. We used three databases: Web of Science and AGRICOLA—both of which searched literature published since 1970—and Forest Science, which searched literature published since 1939. In addition, we included additional references gleaned from publications found in the literature search and from a recent U.S. Department of Agriculture–U.S. Department of Interior Joint Fire Sciences Rainbow Series document on the effects of fire on invasive plant species (Zouhar et al. 2008). The literature search from the databases yielded approximately 2,000 references, which were vetted for appropriate material. Documents were eliminated that dealt with medical issues (e.g., new treatments for burn victims), investigations of ecological processes related to fire but not relevant to the scope of this document (e.g., nutrient cycling and insect infestation), or modeling studies with little empirical data.

We were specifically interested in studies that were experimental and that collected quantitative data on the response of understory herbaceous plants to a fire or thinning treatment. We further narrowed our search to papers that specifically addressed thinning (understory or overstory) and fire. We excluded papers that dealt exclusively with prescribed fire or wildfire because we thought these topics were sufficiently addressed in the two Rainbow Series documents (Brown and Smith 2000; Zouhar et al. 2008). We encourage those who are interested in fire effects on flora to explore these documents. We were also interested in publications that investigated the effects of fire or thinning treatments on rare, threatened, or endangered species (based on a keyword search; see appendix 2 for details). This vetting process yielded 33 references, which are discussed in the "Results" section.

The selected papers were entered into a database. Information was collected on the location of the study, the forest type and age, treatment type, intensity of the treatment, sampling method, and the response. Many papers presented results for both functional groups (e.g., graminoids, forbs) and species-specific responses. Therefore, we present data in separate tables for functional groups and species.

RESULTS

Inland Pacific Northwest

In the context of this document, the Inland Pacific Northwest is that area of Oregon and Washington east of the Cascade Mountains including the eastern slope of the Cascade Mountains (figure 11). The climate in this region is characterized by hot, dry summers, and cool, wet winters. Average annual rainfall at two FFS study sites in this region was 49.9 cm (19.6 inches, in eastern Oregon; Metlen et al. 2004) and 68 cm (26.8 inches, in eastern Washington; Dodson et al. 2008) most of which occurs between September and June (Metlen et al. 2004). Average temperature for each site was 7°C (44.6°F, in eastern Oregon) and 7.5°C (45.5°F, in eastern Washington). In summer, fuels become dry and can support large wildfires (Dodson et al. 2008).

Soil parent material in this region is varied and includes granitic ablation till (McConnell and Smith 1970), volcanic (Busse et al. 2000; Youngblood et al. 2006), nonglaciated sandstone (Dodson et al. 2008), and glacial till (Nelson et al. 2008). Forest vegetation in the Inland Pacific Northwest is mostly ponderosa pine; however, mixed conifer forests (grand fir, white fir, and Douglas-fir) are also common. These types of forests were historically characterized by low- to mixed-severity fires, and fire intervals for low-severity fires were 1 to 25 years. Fires typically consumed forest floor litter and killed less than 20% of the basal area. Mixed-severity fires typically occurred every 25 to 100 years and removed 20% to 70% of the basal area (Hessburg et al. 2005). The result of this type of fire regime is open-canopy, fire-tolerant forests with an abundant herbaceous layer (Wickman 1992; Agee 1993), low fuel beds, and simple canopy layering (Hessburg et al. 2005). At a landscape

Figure 11. A dry forest dominated by ponderosa pine in the Inland Pacific Northwest, Winema National Forest, Oregon. (Scott Roberts, Mississippi State University, Bugwood.org)

scale, low- to mixed- severity fires created a mosaic of burn conditions that ultimately kept areas of high-severity risk isolated (Hessburg et al. 2005). However, current fire-return intervals have increased considerably over the last century (Everett et al. 2000) and have increased the risk of stand-replacement fires.

Multiple factors are responsible for increasing fire risk in the Inland Pacific Northwest; they include livestock grazing, timber extraction, and fire suppression. Livestock grazing has reduced the abundance of fine fuels, which reduces the ability of fires to move quickly across the forest floor (see "Multiple disturbance agents: Herbivory and fire," pages 18–19). The legacy of timber harvesting is a forest of young trees and fire-intolerant species (Hessburg et al. 2005). Since the early 20th century, fire exclusion has occurred in these forests, altering forest structure. Today, the structure of the forests is closed canopy, with abundant trees and shrubs of varying ages that act as ladder fuels (Youngblood et al. 2004). The threat of catastrophic wildfire has motivated managers to design fuel reduction and restoration treatments that increase resilience to stand-replacing disturbances.

We reviewed six papers on fire and thinning treatments in the Inland Pacific Northwest (table 1; see table of contents for table page numbers). Below we discuss relevant results from the studies. Specific results are in table 2 (functional groups) and table 3 (species-specific responses).

McConnell and Smith (1970) estimated herbaceous production in three different thinning treatments in ponderosa pine forests in north-central Washington in the upper Methow River Valley. The elevation of the study site was 716.3 m (2,350 feet). Average July temperature is 21.1°C (70°F). The site averaged 363.2 mm (14.3 inches) of rain and 185.4 cm (73 inches) of snow. Soils were Katar. McConnell and Smith found herbaceous plant production increased with wider spacing of pines. This was true for all functional groups (graminoids, forbs, and shrubs); however, forb production was greater at higher tree canopy covers compared to graminoids and shrubs (table 2).

The FFS program has two sites in the inland Pacific Northwest, in northeast Oregon and in central Washington (figure 10). Elevation at the FFS site in Oregon (Blue Mountains, in northeast Oregon) was 1,040 to 1,480 m (3,412 to 4,856 feet). Temperature averaged 7.4°C (45.3°F), precipitation averaged 500 mm (19.7 inches), and snowfall averaged 66 cm (26.0 inches). Soils were typic Vitrixerands, vitrandic Argixerolls, lithic ultic Haploxerolls, and lithic Haploxerolls (Youngblood et al. 2006). Four treatments were applied: (1) control, (2) thin (thinning relates to understory thinning unless otherwise stated), (3) burn, and (4) thin+burn. Species richness of understory plants in thinned treatments was reduced compared to controls (Metlen et al. 2004). All other comparisons were not significant. However, Youngblood et al. (2006) did *not* find a significant effect of treatment on understory species richness, and neither study found a treatment effect on understory species diversity (Youngblood et al. 2006; Metlen et al. 2004). Ordination analysis of the treatment plots showed that burn-only and thin+burn units were similar to each other and thin-only and control units were similar to each other. When pre- to post-treatment plant community changes were analyzed, burn-only units became more associated with drought-tolerant species; plant communities in thin-only units became more associated with relatively dry, shade-intolerant species; and communities in thin+burn units became more associated with shallow, coarse soils and more drought-tolerant species (Youngblood et al. 2006). Effects of the different treatments at the eastern Oregon FFS site were assessed on different functional groups: graminoids, forbs, and shrubs. The results of these comparisons

are in table 2. Seven species were selected for additional analysis; responses of these species to treatments are presented in table 3.

A second FFS study was conducted in eastern Washington in the Okanogan-Wenatchee National Forest. Elevation was 640 to 1,219 m (2,100 to 4,000 feet; Dolan 2002); average temperature was 7.5°C (45.5°F); average precipitation was 68 cm (26.8 inches); and soils were Haploxerepts, Haploxerolls, Agixerolls, and Haploxeralfs (Dodson et al. 2008). Results showed that species richness increased on thin+burn plots; however, the effect was greatest when prefire species richness was lowest (Dodson et al. 2008). Shrub and forb species richness followed the same pattern (table 2). Graminoid species richness did not increase in response to treatments. Total plant species cover was not affected by treatment type; however, graminoid cover was significantly reduced in burning treatments. Exotic plant cover and richness were low prior to treatment and remained low after treatment, even in the thin+burn treatments where increases in exotic richness were significant (table 2). Ordination analysis did not show any significant or consistent relationships between pre- and post-treatment community change.

Most studies are completed over a short time frame compared to the time of ecological restoration. So, these results are applicable only to immediate (1 to 3 years) responses after the treatment. Busse et al. (2000) measured responses of understory vegetation for 6 years following prescribed fire in the Fremont National Forest, in south-central Oregon. The site had sandy loam or loam soils, 38 to 89 cm (15 to 35 inches) annual precipitation, and average temperatures of 27.7°C (81.9°F) in July and 4.4°C (40°F) in January. While 6 years is still a short time from an ecological perspective, it is longer than most studies. Prescribed burning significantly reduced shrub cover; however, cover of graminoids and forbs was unaffected. Busse et al. (2000) recorded the effects of prescribed fire on two species, antelope bitterbrush and Idaho fescue (table 3). Both species declined significantly after fire and remained below pretreatment levels for the duration of the study.

Another longer term study in this region is from Nelson et al. (2008), who assessed the effects of thinning and burning on the herbaceous understory of multiple forest stands across the eastern Cascades in Washington (Colville, Okanogan, and Wenatchee National Forests). Soils were mostly sandy loams to loams. Average temperature ranged from 14 to 31°C (57.2 to 88°F). Average precipitation ranged from 355 to 760 mm (14 to 29.9 inches). Treatments were applied 3 to 19 years before sampling. Thinning and burning had no effect on native plant richness and cover. Exotic plant cover was higher in thin+burn plots compared to burn-only, higher in thin-only treatments compared to controls, and higher in thin+burn compared to thin-only and controls. Exotic plant richness was higher in thin+burn plots compared to burn-only, and higher in thin-only treatments compared to controls. However, Nelson et al. (2008) note that exotic richness and cover was very low overall: mean exotic cover was 2% in thin+burn stands, and mean exotic richness was only 2.3 species per transect. Functional group responses from this study are summarized in table 2; no species-level data were reported in this study.

Rocky Mountains

The Rocky Mountains extend from northern Canada to central Mexico. Peet (2000) describes four latitudinal regions (Boreal, Central, Southern, and Madrean) and each contains four elevational vegetation zones (foothill, montane, subalpine, and alpine). Soil

Multiple disturbance agents: Herbivory and fire

Like other disturbance agents, fire rarely acts alone. Episodic disturbance agents such as fire, drought, and insect defoliation interact with chronic disturbances such as herbivory by native and domestic ungulates (figure 12).

Figure 12. Bull elk grazing on new shoots in a recently burned area of the 1988 Yellowstone fire. (Jeff Henry, U.S. National Park Service, nps.gov)

Despite the fact that most U.S. dry forests during the past century were dominated by a combination of fire exclusion (Agee, 1993) and high levels of ungulate herbivory (Hobbs 1996), the interaction of herbivory and fire are poorly understood—an obvious management knowledge gap. Wisdom et al. (2006) published an excellent review of this topic, summarized here.

Ungulates' removing fine fuels may reduce the frequency of surface fires but can increase the opportunity for crown fires by enhancing the development of unpalatable trees, providing ladder fuels. Moreover, the combination of fire suppression and ungulate herbivory may favor a substantial increase in density of unpalatable conifers that provide ladder fuels for crown fires, thus repeating the cycle. Such a pattern may partially explain the higher frequency of crown fires in interior forests of the western United States today compared to conditions prior to European settlement.

While scientists recognize the dramatic effects that ungulate herbivory can exert on vegetation development (figure 13), current policies of forest management in North America do not explicitly recognize herbivory as an ecological force. Moreover, the potential effects of ungulate herbivory on processes of vegetation development are generally known, but the magnitude of effects is neither recognized nor easily predicted under different combinations of episodic disturbance, particularly across large landscapes. This lack of predictability poses a substantial obstacle to effective fire and ungulate herbivory management. Traditional models of vegetation transition in forested ecosystems have ignored the influences of ungulate herbivory, while research on effects of herbivory have typically excluded other disturbances.

Wisdom et al. (2006) developed a conceptual model of understory development for montane forests in western North America that considers the combined effects of herbivory and episodic disturbances such as fire (figure 14). This model contrasts strongly with models of forest development that typically focus on overstory dynamics (figure 15). It is intended to complement overstory models and be used as a starting point to develop hypotheses for empirical testing under new research designs that address some of the key knowledge gaps (detailed in Wisdom et al., 2006) related to the interaction of fire and herbivory. The implication is that fire management plans should not be developed in isolation from other management plans such as forest health and range management. This also suggests that assessments of fire's cumulative effects should not just evaluate temporal and spatial effects of multiple fires but also cumulative effects of multiple disturbances.

Figure 13. Regrowth in a forest burned 4 years earlier demonstrates the effects of herbivory by cattle, mule deer *(Odocoileus hemionus)*, and elk *(Cervus elaphus)* on vegetation development within summer range in eastern Oregon. The area at left, subject to extensive herbivory by the three ungulate species after the wildfire, is dominated by grass species of low palatability such as pinegrass *(Calamagrostis rubescens)*. The area at right, excluded from ungulate herbivory after the fire, is dominated by highly palatable aspen *(Populus tremuloides)* and snowbrush ceanothus *(Ceanothus velutinus)*. (Wisdom et al. 2006)

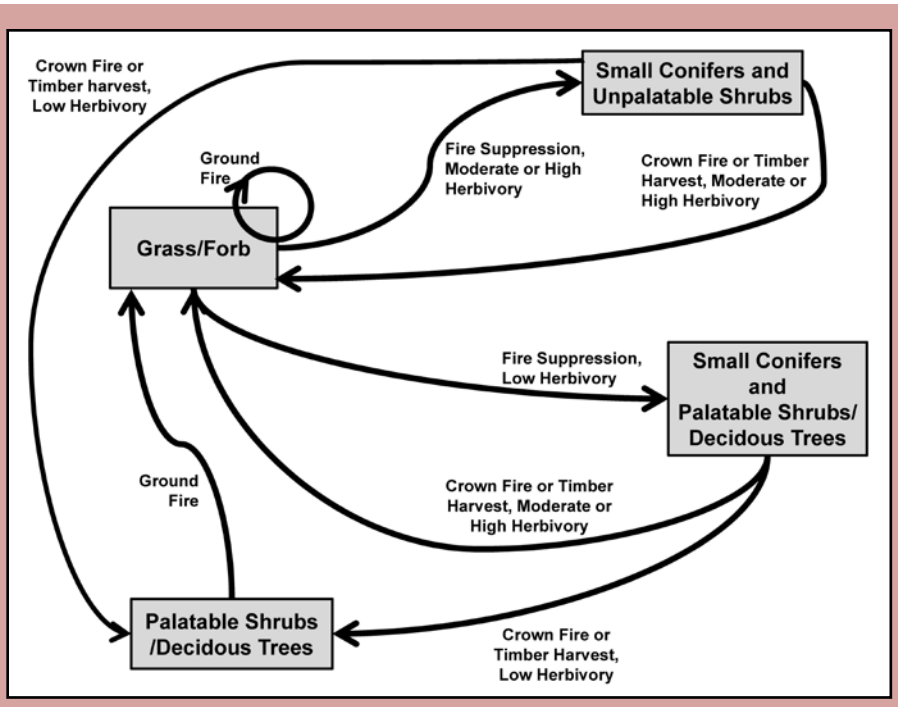
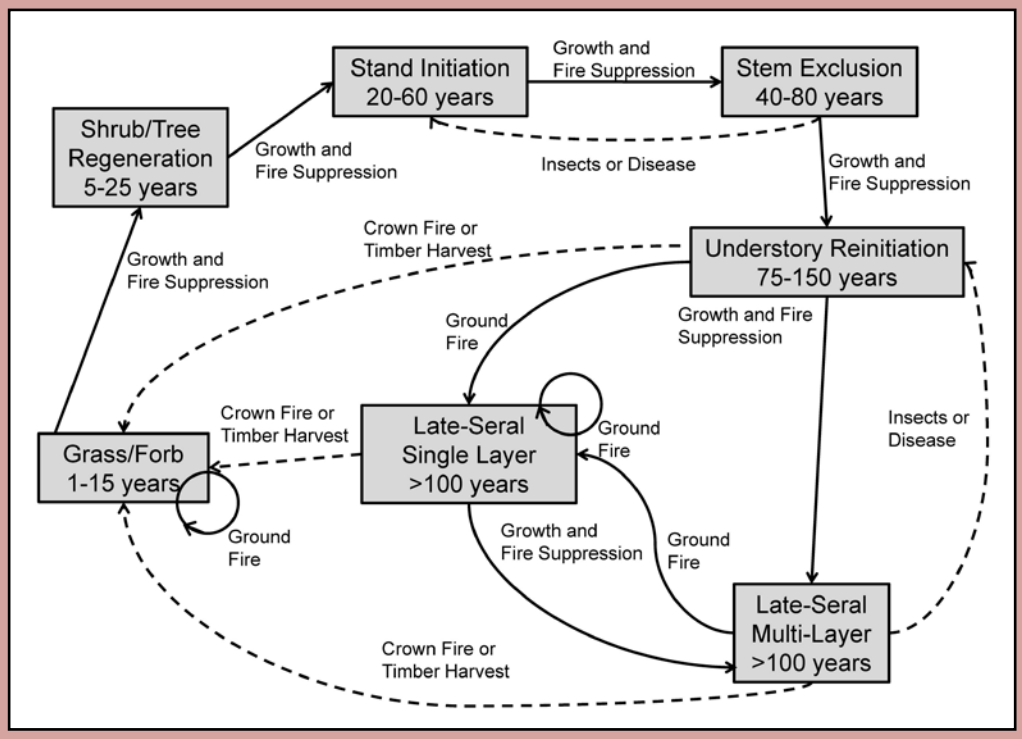


Figure 14. Conceptual model of understory plant development and dominance in montane forests of western North America, as influenced by varying densities of wild or domestic ungulates, interacting with episodic disturbance regimes of fire and timber harvest. Gray boxes are vegetation states, arrows are transitions between states, with the associated disturbance agents of herbivory, fire, and timber harvest that cause transition to the vegetation states. Dominant life forms of plants in each understory state are given. (Wisdom et al. 2006)

Figure 15. A sample vegetation–disturbance model for montane forests of western North America, considering the effects of episodic disturbances. The model is based on concepts of vegetation states and transitions, including multiple steady states, potential threshold effects, and abrupt transitions caused by episodic disturbances. Gray boxes are vegetation states; arrows are transitions between states, with the associated disturbance agents of fire, insects, disease, and timber harvest that cause transitions. Notably absent are transitions caused by ungulate herbivory, alone or in combination with episodic disturbances. Also absent are details about understory composition of vegetation for many of the vegetative states and the potential transitions brought about by the interactions between understory and overstory development of vegetation. Wisdom et al. (2006) hypothesize that the dashed arrows represent transitions and resulting states that are more likely to occur under moderate or high levels of ungulate herbivory. For such transitions, forest managers typically assume that such effects are brought about solely by disturbances of fire, insect, disease, or timber harvest. (Wisdom et al. 2006)



parent material in the Rocky Mountains is composed mostly of Precambrian granites (Peet 2000). Average annual temperatures in the studies reported here ranged from 7 to 7.5ºC (44.6 to 45.5ºF; Covington et al. 1997; Fulé et al. 2002; Wienk et al. 2004; Dodson and Fiedler 2006; Metlen and Fiedler 2006; Moore et al. 2006; Dodson et al. 2008; Laughlin et al. 2008). Annual precipitation ranged from 50 to 60 cm (19.7 to 23.6 inches) in the central Rockies (Uresk and Severson 1998; Wienk et al. 2004; Dodson and Fiedler 2006; Metlen and Fiedler 2006; Dodson et al. 2008) and from 36.8 to 57 cm (14.5 to 22.4 inches) in the southern Rockies (Fulé et al. 2002; Moore et al. 2006; Laughlin et al. 2008).

At higher elevations, high-intensity, low-frequency fires were common; these were typically stand-replacing fires. At lower elevations, in drier forests dominated by ponderosa pine, low-intensity, high-frequency fires were the norm; fire-return intervals were as frequent as 5 to 14 years but more typically were 20 to 40 years (Peet 2000).

Under historical fire intervals, regeneration in ponderosa pine forests was often episodic; seed germination and seedling establishment depended on favorable weather. Frequent low-intensity fires maintained an open parklike appearance to the stands with a thick, diverse understory of herbaceous plants. The low-intensity fires removed accumulated litter and killed young woody plants. With less frequent and more severe fires, regeneration of fire-tolerant forests may be slowed because of the high density of fire-intolerant species and the lack of a seed source (Peet 2000).

Central Rocky Mountains

In this document, the central Rocky Mountains includes Colorado, Idaho, Montana, North and South Dakota, Utah, and Wyoming (figure 16a). We reviewed six papers that presented results from this region (table 1). Below, we discuss relevant results from the studies. Specific results are in table 4 (functional groups) and table 5 (species-specific responses).

Uresk and Severson (1998) measured understory response in ponderosa pine forests to variable thinning treatments in the Black Hills Experimental Forest in South Dakota where elevation ranged from 1,620 to 1,800 m (5,315 to 5,906 feet), precipitation averaged 60 cm (23.6 inches), and soils derived from metamorphic rock. They thinned plots at six levels in two stands of different ages (pole size and sapling size). Treatments were thinned to 5 m^2/ha (21.8 square feet/acre), 9 m^2/ha (39.2 square feet/acre), 14 m^2/ha (61.0 square feet/acre), 18 m^2/ha (78.4 square feet/acre), 23 m^2/ha (100.2 square feet/acre), and 28 m^2/ha (122.0 square feet/acre) and an unthinned control. The control for pole-size stems was 37 to 40 m^2/ha (161.2 to 174.2 square feet/acre); for sapling-size stems it was 27 to 33 m^2/ha (117.6 to 143.7 square feet/acre). Uresk and Severson (1998) also included a clearcut treatment; however, we will not report the results of this treatment because it is outside the scope of this document. Measurements were repeated in 1974, 1976, and 1981. In general, in sapling and pole-size stands, production (kg/ha or lb/acre) of all understory functional groups (graminoids, forbs, and shrubs) increased with decreasing basal area. A summary of the results for functional group categories is in table 4. Species responses are summarized in table 5.

Wienk et al. (2004) studied the effects of fire and thinning in a ponderosa pine forest ecosystem in the northern Black Hills in South Dakota, where elevation ranged from 1,220 to 1,280 m (4,003 to 4,199 feet), precipitation averaged 54 cm (21.3 inches), winter temperature averaged -3°C (26.6°F), summer temperature averaged 18°C (64.4°F), and

Figure 16a–b. At left, an example of the dry forests in the Central Rocky Mountains: a ponderosa pine–Douglas-fir forest along the Blackfoot River, in Montana. (Bureau of Land Management, U.S. Department of Interior, blm.gov) At right, a ponderosa pine forest in the Southern Rocky Mountains of northern Arizona. (James N. Long, Utah State University, Bugwood.org)

soils were of the Vanocker series. They applied two treatments in all combinations: burn and no burn; and no cut, partial cut, and clearcut. Clearcut treatments will not be discussed here because they are outside the scope of this document. Species richness increased as cutting intensity increased in the no-burn plots (no-burn+partial-cut to no-burn+no-cut). Species richness was also higher in the burn+no-cut treatment compared to the no-burn+ no-cut treatment. The results of the functional groups and species responses are summarized in tables 4 and 5, respectively.

Dodson and Fiedler (2006) and Metlen and Fiedler (2006) published results from the FFS study site in western Montana at the University of Montana Lubrecht Experimental Forest, where elevation was 1,263 to 1,388 m (4,143.7 to 4,553.8 feet), temperature averaged 7°C (44.6°F), precipitation averaged 50 cm (19.7 inches), and soils were mixed Eutric Haplocryalfs, and mixed, frigid, Typic Dystrocryepts (figure 10; Dodson 2004). The forest studied was primarily ponderosa pine and Douglas-fir with some western larch and lodgepole pine. Dodson and Fiedler (2006) focused on the response of invasive, exotic plants to prescribed fire, thinning, and thinning plus prescribed fire (tables 4 and 5, respectively). They found that *transformer exotic cover*—exotic plants with the potential to alter ecosystem dynamics (Richardson et al. 2000)—increased with increases in canopy openness, crown scorch height, and cover of duff, litter, and slash (Dodson et al. 2008). Metlen and Fiedler (2006) focused their results on the response of all understory plants (table 4). Ordination of plant community responses showed that burn-only and thin+burn treatments were similar to each other and thin-only and control treatments were similar to each other.

A follow-up study by Dodson et al. (2007) documented response of common and uncommon understory species in the FFS sites. Common species (defined as occurring in more than 33% of plots) increased in the thin treatments compared to controls. Uncommon species (defined as occurring in less than 10% of plots) increased in the thin+burn plots compared to controls. In addition, they found that native and exotic species responded similarly to treatments. Indicator species of the three treatments are in table 5.

Southern Rocky Mountains

In the context of this document, the Southern Rocky Mountains include Arizona and New Mexico (figure 16b). We reviewed five papers that presented results from this region (table 1) and discuss relevant results below. Specific results are in table 6 (functional groups) and table 7 (species-specific responses).

Covington et al. (1997) collected preliminary data on the effect of thinning and fire+ thinning on understory vegetation in ponderosa pine forests in Arizona. The study was performed in an old-growth forest, the G.A. Pearson Natural Area, which had never been harvested. Elevation was 2,195 to 2,256 m (7,200 to 7,400 feet). Average temperature was 7.5° C (45.5°F). Average precipitation was 56.6 cm (22.3 inches). Soils were montmorillonitic complex of frigid Typic Argiborolls and Argiboralfs.

Three treatments were applied: (1) thin only—all presettlement trees and trees more than 16 inches (40 cm) DBH were retained; (2) thin+burn—same thin treatment plus all litter and duff layers removed and grass fuels added (approximately 600 lb/acre [669 kg/ha]); and (3) controls. They found herbaceous biomass production was greatest in the two treatments compared to the controls.

Moore et al. (2006) expanded this research to further investigate trends and to collect long-term data. Between 1995 and 2004, total herbaceous standing crop biomass was greater in the thin and thin+burn groups compared to the controls, although the two treatments were not different from each other. Moore et al. (2006) also investigated trends in specific functional groups (table 6). C3 graminoid (i.e., "cool-season grass") standing crop was higher in the treatment groups compared to the no-treatment group in all years (1994–2004); however C4 graminoid (i.e., "warm-season grass") standing crop did not differ among any group in any year. Additional work in this system reveals that effects of treatments (fire and thinning) may take years to reveal themselves, if responses are detected at all.

Laughlin et al. (2008) continued monitoring the forest treatments originally performed by Covington et al. (1997). They analyzed the response of plant communities 12 years after treatment. Species richness in the thin+burn treatment area significantly diverged from the thin and control treatments after 11 and 12 years (2005 and 2006); species richness was higher in the thin+burn treatment after that time. In addition, they performed indicator species analysis on the effects of thinning and burning (table 7).

Griffis et al. (2001) also investigated the effects of thinning, burning, and thin+burn on understory plant composition in ponderosa pine forest in the Coconino National Forest in Arizona (elevation 2,150 to 2,500 m [7,054 to 8,202 feet]). They analyzed results for abundance and species richness of the following functional groups: native and non-native forbs and native and non-native graminoids (table 6). The control, thin, and thin+burn plots had greater species richness of native graminoids than the wildfire plots.

Fulé et al. (2002) studied thinning at different intensities plus burning in northern Arizona, in the Kaibab National Forest, where elevation was 2,290 m (7,513 feet), precipitation averaged 36.8 cm (14.5 inches), temperatures ranged between 8 and 29°C (46.4 to 84.2°F), and soils were fine, smectitic, mesic, Vertic Paleustalfs, and Haplustalfs. They found that species richness of understory vegetation decreased significantly from 1997 to 2000 (the study period). In addition, differences among treatments were rare and inconsistent,

indicating that factors other than treatments were responsible for the observed differences. Non-native species were highest in the control treatments, and no non-native species were recorded in the burn treatments. The most abundant non-native species recorded were cheatgrass, common dandelion, white clover, and common mullein. The percent of native species increased in all treatments except the minimum restoration treatment.

Sierra Nevada

The area included in this region is the midmontane forests of the Sierra Nevada Mountains in California (figure 17). The climate is Mediterranean, which is characterized by hot, dry summers and cool, wet winters. Average annual rainfall ranges between 85 and 100 cm (33.5 to 39.4 inches; Barbour and Minnich 2000), most of which occurs in winter and spring (Collins et al. 2007). Average low and high temperatures at one study site used in this document (Collins et al. 2007) were 0 to 8ºC (32.0 to 46.4ºF, in January) and 10 to 29ºC (50.0 to 84.2ºF, in August). Soils are often Alfisols or Ultisols, and Inceptisols are found on steeper slopes (Barbour and Minnich 2000).

Forest vegetation is mixed conifer with several co-dominant species: white fir, incense-cedar, ponderosa pine, Jeffrey pine (in southern California), and Douglas-fir (Barbour and Minnich 2000). The historical fire regime in this region is hypothesized to be low-severity with return intervals of 4 to 20 years (Barbour and Minnich 2000). The frequent, small (1 to 800 ha [2.5 to 1,976.8 acres]), low-severity fire regime resulted in a forest stand structure with pole-size and larger trees. Fire suppression has resulted in forest stands that have higher densities of small trees (10 to 30 cm [3.9 to 11.8 inches] DBH) and low recruitment to the largest size classes (DBH more than 61 cm [24 inches]), which has resulted in tree densities that are historically higher (Barbour and Minnich 2000).

We reviewed two papers that presented results from the Sierra Nevada region (table 1). We discuss relevant results from the studies below. Specific results are in table 8 (functional groups) and table 9 (species-specific responses).

Collins et al. (2007) conducted an FFS study at the University of California Blodgett Forest Research Station, where elevation was 1,100 to 1,410 m (3,609 to 4,626 feet), precipitation averaged 160 cm (63 inches), January temperatures ranged from 0 to 8°C (32 to 46.4°F), summer temperatures averaged 10 to 29°C (50 to 84.2°F), and soils were fine-loamy, mixed, semiactive, mesic Ultic Haploxeralfs (figure 10). In this study, the thin-only treatment is described as thinning from below combined with a mechanical mastication treatment. Shrub cover was lower

Figure 17. Mixed conifer forest at the Teakettle Experimental Forest in the Sierra Nevada Mountains. (Malcolm North, University of California–Davis, teakettle.ucdavis.edu)

in mechanical-only treatments compared to control. Cover of forbs and graminoids was not significantly different in any treatment plot compared to control. Treatments had no effect on native cover, but richness decreased after mechanical-only and mechanical+burn treatments compared to control. Exotic species cover increased after mechanical+fire treatment compared to control and fire-only. Exotic richness increased after mechanical-only and mechanical+burn treatments compared to control and fire-only. Results are summarized in table 8.

Wayman and North (2007) investigated the effects of fire (burn, no-burn) and thinning (understory, overstory, and no-thin) on plant communities in Teakettle National Forest, California, where elevation was 1,900 to 2,200 m (6,234 to 7,218 feet), precipitation averaged 125 cm (49.2 inches), and soils were well-drained, mixed, frigid Dystric Xeropsamment. Species richness increased after burn+understory-thin and burn+overstory-thin treatments compared to all other treatments. Species richness after burn+overstory-thin significantly increased over pretreatment levels. Shrub cover was significantly reduced from pretreatment levels in the following treatments: (1) no-burn+understory-thin, (2) no-burn+overstory-thin, (3) burn+no-thin, and (4) burn+overstory-thin. Herbaceous cover was significantly greater in burn+understory-thin and burn+overstory-thin treatments compared to all other treatments. Table 9 describes responses of individual species. Ordination analysis showed that post-treatment species composition of understory plant communities changed significantly from pretreatment in the following plots: (1) burn+understory-thin, (2) burn+overstory-thin, and (3) no-burn+overstory-thin. All three treatments were negatively associated with plant communities requiring high canopy cover. The two burn treatments were additionally related to plant communities affiliated with bare ground.

Southeastern United States

The area included in this document is the pine forests of the Southeastern Coastal Plain and Southeastern Piedmont (figure 18). The climate in this region is humid subtropical. Average temperatures range between 0 and 18°C (32 to 64.4°F) during the coldest months and exceed 22°C (71.6°F) during the hottest months (Christensen 2000). Average annual rainfall in this region ranges between 70 and 130 cm (27.6 to 51.2 inches), most of which occurs during summer (Christensen 2000). Winter hurricanes and summer convective storms provide much of the rainfall. Associated with these storms are high frequencies of lightning strikes (figure 3), which are sources of fire ignition. Soils in this region are infertile and are characterized by Entisols and Inceptisols. Alfisols and Ultisols are found in more fertile areas (Christensen 2000).

The xeric forest communities in this region are classified as xeric longleaf pine woodlands, subxeric longleaf pine woodlands, and sand pine scrub. Forest vegetation in the xeric and subxeric longleaf pine communities is dominated by longleaf pine with a subcanopy of oaks (Christensen 2000). Sand pine scrub is dominated by sand pine with a subcanopy of oaks and saw and scrub palmetto (Christensen 2000). The Southeastern Coastal Plain ecotype hosts a large number of fire-dependent native understory plants.

The Southeastern longleaf pine forests had a frequent fire-return interval, 3 to 10 years, and some areas can burn as often as every year. Sand pine communities had a longer return

interval, 30 to 60 years. The frequent return interval is due to several factors including the following:

1. High occurrence of lightning strikes exists in the region (the highest in the continental United States).
2. Historically, Native Americans and later European Americans used fires frequently for forest management.

Figure 18. The longleaf pine and wiregrass ecosystem, such as this one in South Carolina, was once common throughout the Southeastern Coastal Plain. Today, fire suppression practices have facilitated the loss of this ecosystem type. (Ricky Layson, Ricky Layson Photography, Bugwood.org)

Forests with fire regimes of this nature were open-canopied and broadly spaced with an abundant herbaceous understory. Fire exclusion has been practiced in the Southeastern Coastal Plain for much of the 20th century. As a result, forests are closed-canopy systems dominated by pines and hardwoods, and they have a less diverse and productive understory herbaceous community.

We reviewed three papers that presented results from the Southeastern United States region (table 1). Below, we discuss relevant results from the studies. Specific results are in table 10 (functional groups) and table 11 (species-specific responses).

Harrington and Edwards (1999) studied thinning and burning in a longleaf pine plantation at the Savannah River Site in South Carolina. Soils were of the Blanton, Lakeland, and Troup series. Stands were 8 to 11 years old, all treatments had prescribed burns, and one of four treatments was applied to each stand: (1) burn only (control), (2) pine thinning, (3) nonpine woody species thinning with herbicide, and (4) both pine and woody species thinning with herbicide. Results are presented only for the burn-only and pine thinning, because a discussion of herbicide effects is outside the scope of this document. Table 10 describes specific results. In general, understory species responded positively to thinning and burning treatments.

Provencher et al. (2001) studied thinning and burning in northern Florida at the Elgin Air Force Base, where elevation is 0 to 100 m (0 to 328 feet), temperature averaged 18.3°C (64.9°F), precipitation averaged 158 cm (62.2 inches), and soils were Lakeland series. There were four treatments: control, prescribed burn, prescribed burn+herbicide, and prescribed burn+felling. The herbicide treatment is not discussed here because it is outside the scope of this document. In general, treatments had no effect on the density of the different functional groups, with the exceptions of the following:

1. Legumes, which had lower density 1 and 2 years after treatment
2. Graminoids, which had higher density 4 years after treatment
3. Shrubs, which had lower density 2 years after treatment (table 10)

Species responses, which varied, are presented in table 11.

Phillips and Waldrop (2008) published results from the FFS site at the Clemson Experimental Forest, in South Carolina, where elevation was 200 to 300 m (656 to 984 feet), temperature averaged 15.3°C (59.5°F), precipitation averaged 138 cm (54.3 inches), and soils were Ultisols of the Cecil-Lloyd-Madison association (figure 10). This forest is second-growth loblolly pine, shortleaf pine, and a variety of oaks and hickories. An ordination analysis of post-treatment species compositional changes showed that, over time, treatment units became more associated with early seral species and xeric soil conditions. Table 10 summarizes results from the functional group analyses.

Eastern Deciduous Forest

The Eastern Deciduous Forest represents a large, diverse ecotype in the eastern portion of the United States (figure 19). This ecotype is bounded to the north by the boreal forest, on the west by the prairie grasslands of the Midwest, and on the south and east by the Southeastern Coastal Plain forests (Delcourt and Delcourt 2000). This large area supports a great variety of forest types.

Characteristics of the study sites reported in this document are as follows:

Study site	Average temperatures (°C / °F)	Average precipitation (cm / inches)	Soil type(s)	Reference
North Carolina	17.6 / 63.7	163.8 / 64.5	Evard and Cliffield	Waldrop et al. 2008
Ohio	11.3 / 52.3	102.4 / 40.3	Steinberg and Gilpin series silt loams	Waldrop et al. 2008
Kentucky and Tennessee	15.5 / 59.9	121 / 47.6	Bodine, Baxter, and Hammock	Franklin et al. 2003
Missouri	13.3 / 55.9	112 / 44.1	Weathered Alfisols and Ultisols	Zenner et al. 2006

Fire in the Eastern Deciduous Forest was thought to be primarily confined to ecozones near transitions; e.g., prairie and oak–hickory forest in the west; Southeastern Coastal Plain pine forests and Southeastern pine forests (Delcourt and Delcourt 2000). However, recent publications address the influence on the Eastern forests of Native Americans' use of fire (Brose et al. 2001). Small ground fires were used to clear the forests for hunting and agriculture, resulting in oak-dominated forests with a diverse herbaceous understory (Brose et al. 2001). Twentieth-century fire suppression has resulted in forests that are dominated by fire-intolerant, mesic forest species. However, due to the relative lack of understanding of the role of fire in these forests compared to other ecotypes in the West and Southeast (Brose et al. 2001; Waldrop et al. 2008), little information is available on the role of fire in restoring oak regeneration to the Eastern Deciduous Forest and the effects on the herbaceous understory.

We reviewed three papers that presented results from the Eastern Deciduous Forest region (table 1). Below, we discuss relevant results from the studies. Specific results are in table 12 (functional groups) and table 13 (species-specific responses).

Figure 19. Eastern deciduous forest. (Steven Katovich, USDA Forest Service, Bugwood.org)

Franklin et al. (2003) studied the effects of thinning and burning in oak forests on mesic and xeric sites at the Land Between the Lakes National Recreation Area in Kentucky and Tennessee. The xeric site treatments were control, dormant-season burn, two consecutive dormant-season burns, shelterwood cut, and shelterwood cut+burn. Herbaceous cover on xeric sites increased most in plots that were cut and burned compared to burn-only, cut-only, and control plots.

Zenner et al. (2006) studied the effect of different levels of harvest on graminoid, legume, and woody vine covers. This study was conducted in the Ozark Highlands in southeast Missouri in 40-year-old oak hickory forests, where elevation was 170 to 360 m (558 to 1,181 feet). Treatments were single-tree selection, group selection, thinning, no cut, and clearcut. The clearcut treatment is not discussed here because it is outside the scope of this document. Cover and richness of understory vegetation increased as harvest intensity increased. Functional group responses are reported in table 12.

The results of two FFS areas are reported in Waldrop et al. (2008). One area was at the Green River Game Land in western North Carolina, where elevation was 366 to 793 m (1,200 to 2,600 feet) (figure 10). This site was 80- to 120-year-old mixed oak–pitch pine forest. The second site was in the Allegheny Plateau region of southeast Ohio, at the Raccoon Ecological Management Area, the Zaleski State Forest, and the Tar Hollow State Forest. There, elevation was 207 to 330 m (678 to 1,082 feet) (figure 10). The forests were more than 100 years old and were dominated by oaks and hickories in the overstory and by maples in the understory. At the Green River site, forb and graminoid cover increased in the third year after a thin+burn treatment. Shrub responses varied. At the Ohio Hills site, forb cover increased in the fourth year post-treatment in the burn-only and thin+burn treatments. Graminoid cover increased in the first year post-treatment in the thin-only and thin+burn plots. By the fourth year post-treatment, however, graminoid cover was increased in the burn-only and thin+burn treatments. At the Ohio Hills site, as at Green River, shrub responses varied. Results from the Ohio and North Carolina sites are in tables 12 and 13, respectively.

Effects of fire on rare, threatened, or endangered plants

Seven studies have been conducted on the effects of fire and thinning on herbaceous species of conservation concern (table 14). Many of the species studied are thought to be fire dependent. Investigations were conducted to determine response to prescribed fire and, in some cases, the fire-return interval necessary for positive population growth. The studies included here are mostly from the Southeastern United States; one is from the Inland Pacific Northwest.

Harrod and Halpern (2009) investigated the effects of season of burn on two species of rare plants in Washington: longsepal wild hollyhock and Thompson's clover. They found that plant response to fire was more variable among populations than among treatments. Survival of adult longsepal wild hollyhock was high among all treatments and sites, although seedling survival was low. Survival of mature Thompson's clover could not be calculated due to high rates of dormancy. Thompson's clover seedling survival ranged from 40% to 100% in the first year of the study and from 28.1% to 72.2% in the second year. In the second year, seedling survival of Thompson's clover was higher in a spring burn at one site and higher in spring and fall burns at a second site. Results are summarized in table 15.

Young et al. (2007) published a study on the reproductive ecology of a federally endangered legume (cobwebby wild indigo) in Georgia and compared it with a common legume (gopherweed) in the same genus. The fire-related part of the study is the effect of heat shock on germination. The federally endangered species had a much narrower temperature tolerance for germination than the common species. Cobwebby wild indigo had a 2% germination rate between 60 and 100ºC (140 and 212ºF), whereas gopherweed had 40% germination rate at all temperatures tested. Results are summarized in table 15.

Franklin et al. (2006) investigated the effect of prescribed fire on stem number and pollen viability of the rare rough-leaf loosestrife in North Carolina. After the fire, stem number decreased in two populations and increased in one. Pollen viability was not significantly affected by prescribed fire. Fruit production was higher postburn in one population.

Kirkman et al. (1998) studied the effects of prescribed fire and mowing on the demography of a federally endangered plant, chaffseed. Their study sites were on the lower coastal plain in Georgia. They found that fire in either the dormant or growing season increased flowering response in the next growing season after fire. The response was limited to that one year; however, when fire treatments stopped, the density of flowering individuals decreased. Density of reproductive individuals was higher in the burn treatments than in the control or mow treatments. Researchers also found no difference in mortality due to season of burn. In addition, control plots had a lower flower-to-fruit production ratio, indicating that lack of fire will reduce reproductive output in this plant. The mowing treatment in this study produced results that were rarely different from control plot results and, therefore, mowing is not an equivalent disturbance on the demography of this plant. However, a follow-up study by Norden and Kirkman (2004) did not find any long-term beneficial effects of burning on chaffseed. Densities of plants in all plots had returned to 1992 levels by 2001, 6 years after the treatments were concluded.

Carrington (1999) studied postfire seedling establishment of four herbaceous and one shrub species in the Florida sand pine scrub. Four species were vulnerable to extinction—Ashe's calamint, Feay's palafox, garberia, and longleaf buckwheat (or scrub buckwheat)—and

one, Florida alicia, was secure (NatureServe 2008). Carrington followed resprouting and flowering of plants in prescribed burned areas and in an unburned area. Randomly selected plants in each area were used in the study. Four of the five species resprouted after prescribed fire. Of those four species, one (longleaf buckwheat) had a greater proportion of plants flowering 5 months postfire compared to 19 months postfire. And the proportion of plants flowering was greater in burned than unburned areas. A second species, Feay's palafox, displayed the opposite pattern: flowering was greater 19 months postfire compared to 5 months postfire; however, flowering in this species was also greater in burned than unburned areas. Two other species, Florida alicia and garberia, had a similar proportion of flowers both 5 and 19 months postfire. Like the other taxa, both these species had a greater proportion of flowers in burned than unburned areas. Also, plots centered on the focal species had a higher number of seedlings postfire than in random plots. Results are summarized in table 15.

Satterthwaite et al. (2002) performed a population viability analysis (PVA) on a federally threatened and state (Florida) endangered plant, longleaf buckwheat, to determine fire's effects on the species' demography. Researchers found that under optimistic fertility estimates, unburned populations would remain stable but burned populations would grow rapidly. Under pessimistic fertility estimates, unburned populations would decline and burned populations would remain stable. In addition, they performed a PVA with a stochastic fire interval and found that as fire interval increased so did the probability of extinction in longleaf buckwheat.

Weekley and Menges (2003) performed an observational study on the effects of fire on 12 species of native plants of the Florida scrub ecosystem. Ten of the 12 species studied are threatened or endangered at the state or federal level. Eight of 12 species resprouted after fire. Of those eight species, three showed decreased sprouting after fire. Individuals that resprouted after fire were often smaller than the preburn size. A community analysis of the burn plots showed that after treatment, species richness declined in 10 of 12 burn plots (average decline 9.4%). Species that were lost included epiphytic bromeliads, terrestrial lichens, and nonsprouter species (e.g., Small's jointweed). However, herb species richness increased, and 15 of 17 herbs species increased in abundance. Results are summarized in table 15.

Menges et al. (2006) performed population viability analysis on an endemic Florida scrub mint, scrub balm. They found that fire was essential for the long-term viability of this species. Furthermore, the optimal fire interval was 6 to 12 years.

DISCUSSION

In general, fire and thinning treatments increased response of understory species. More intense treatments, such as combined thin+burn treatments and greater thinning intensity, had the highest increases in cover and production. Thin-only and burn-only treatments had more moderate increases. In addition, most studies found increased response of exotic plants to increasing disturbance intensity; however, most studies report very low invasive presence even after the treatments. If one of the goals of the forest management plan is to increase presence or cover of understory species in general, then prescribed fire and thinning treatments may be a viable option to restore forest understory.

Rare, threatened, and endangered species in dry forest environments often respond favorably to prescribed fires. Many of the species reported in this document increased in abundance or reproduction or were unaffected by fire, indicating that prescribed fire is compatible with (or beneficial for) restoration of these species.

In the following sections we discuss aspects of fire and thinning treatments that need to be considered in the planning process, and we indicate areas for future research (see the "Areas for future research …" text box).

Areas for future research on the effects of fire management treatments on understory vegetation

1. What sort of impacts do alternative active thinning treatments (e.g., mastication and herbicide) have on understory vegetation, and how do they interact with prescribed fire?
2. To what extent are the initial understory species composition and post-treatment understory species composition similar? If dissimilar, what are the dissimilarities, and what mechanisms cause them?
3. What impact does season of burn or other treatment have on understory vegetation?
4. What are the effects of multiple disturbances over time (e.g., reburns) on understory vegetation restoration?
5. What are the mechanisms of understory plant species' response to method of thinning?
6. How does stand age impact understory response?
7. How well are these short-term results extrapolated to the long-term?

Intensity, frequency, and season of disturbance

Disturbance creates open areas for plants to colonize, releases nutrients to the system, and can increase light available to understory species. As disturbance levels increase, more space, nutrients, and light become available. In studies that compared single disturbances (e.g., thin or burn) to combined treatments (thin+burn), thin+burn study plots had higher species richness (Griffis et al. 2001; Wienk et al. 2004; Dodson and Fiedler 2006; Metlen and Fiedler 2006; Collins et al. 2007; Dodson et al. 2007; Wayman and North 2007; Dodson et al. 2008; Laughlin et al. 2008; Nelson et al. 2008; Phillips and Waldrop 2008). However, see Fulé et al. 2002; Metlen et al. 2004; and Youngblood et al. 2006.

In addition, thin+burn plots had higher species richness of exotic plants (figure 20); see Griffis et al. 2001; Dodson and Fiedler 2006; Metlen and Fiedler 2006; Collins et al. 2007; Dodson et al. 2008; and Nelson et al. 2008. However, results from these studies indicate native and exotic plants invade areas via similar mechanisms. While increased disturbance levels facilitate exotic establishment, the same disturbance levels also facilitate native establishment. This is positive for forest restoration because it indicates that exotic species do not spread by novel mechanisms which are difficult to control. Regardless, care should be taken when performing restoration treatments near areas with high levels of exotic plants, such as

gardens associated with homes in the wildland–urban interface (WUI). In these areas, treatments should disturb less of the forest floor to prevent open space for exotics to colonize.

Figure 20. Common mullein is an invasive plant often seen in treated stands that are the focus of many studies in this document. The invasion above is in the Wheeler Point Fire area of Umatilla National Forest. (Dave Powell, USDA Forest Service, Bugwood.org)

Many of the studies included in this document conclude that multiple entries into a forest are needed to properly restore the understory to the historical range of variation (Harrington and Edwards 1999; Metlen and Fiedler 2006; Laughlin et al. 2008; Waldrop et al. 2008). Few studies have followed systems over multiple entries; however, Laughlin et al. (2008) followed a restoration for more than a decade after multiple entries. In that system, there was an immediate, positive response to herbaceous production. However, differences in species richness took much longer to occur; species richness was higher in treated areas compared to controls only after 11 years. The results from this long-term study indicate that restoration of the understory to historical variability is a long-term process involving repeated prescribed burns.

The Laughlin et al. (2008) data also provide another important lesson: fire has been actively suppressed for most of the last century, and restoration management of the forests is relatively new; therefore, it may take multiple treatments to restore a forest. In addition, it may take many years before the effects of the treatments are fully realized. Results also depend on the pretreatment condition of the area. Dodson et al. (2008) found that treatments did affect understory plant response, but the degree of the response depended on the pretreatment condition of the forest; i.e., greater responses were observed in treatment plots with lower initial values. One reason Dodson et al. (2008) were able to document this effect was the Before–After, Control–Impact design of the FFS study. Instead of collecting data only in an unmanipulated "control" plot, pretreatment data at all study locations were also collected. This is a powerful experimental design that should be encouraged in future investigations of forest restoration.

Methods of thinning vary widely across the United States. In some regions, mastication is used to remove smaller trees. Herbicide is a common practice in the southeast United States. In addition, while not used as a thinning treatment per se, grazing by domestic ungulates is a common practice in western states. These treatments were outside the scope of this document; however, it is important to understand how they interact with fire and thinning treatments (see "Multiple disturbance agents: Herbivory and fire," page 18–19).

Another consideration is season of disturbance. In many regions, prescribed fire is conducted outside the historical fire season. Often for safety reasons, prescribed fire is conducted in when fuel moisture conditions are higher (e.g., early spring or late fall). More research—perhaps in highly controlled, small-scale situations—is needed to understand these dynamics. In addition, the effects of low-severity prescribed fires may be different

from high-severity prescribed fires or stand-replacing fires; for example, greater exotic species richness in high-severity fires (Griffis et al. 2001). Additional research is needed on the utility of more severe fire to restoring understory plant communities.

Seed sources

After a disturbance, plants can recolonize in a variety of ways. Some plants will survive the disturbance with underground rhizomes or with other perennial underground tissue. This tissue allows rapid regrowth after the disturbance (Carrington 1999; Weekley and Menges 2003; Harrod and Halpern 2009). Other species will germinate from seeds stored in the soil seed bank. And still others will need to be dispersed to the disturbed site from other stands In all cases, it may be unclear whether a given species will remain as part of the community after the disturbance or which species will join the community after the disturbance. This is likely a function of the presence of source populations, which in turn is a function of the landscape mosaic surrounding the treated stand. In many of the studies presented here, new species were found in the postdisturbance community (Carrington 1999; Weekley and Menges 2003). Therefore, when assessing the impact of a prescribed disturbance on the plant community, it will be useful to keep in mind recolonization and life-history strategies by different species.

Some scientists have investigated the usefulness of life-history strategies for predicting the response of plants to disturbance (Chapman and Crow 1981, McIntyre et al. 1995). The utility of using this approach is mixed; McIntyre et al. (1995) found that life form was the best predictor of response, while Chapman and Crow (1981) found that species within life form categories had a broad array of responses. Nevertheless, understanding where the perennating tissue of a plant resides is a useful place to start when predicting plant response to disturbances, including prescribed fire and mechanical thinning.

Time since disturbance

The majority of studies presented in this document only note short-term changes in plant community composition, usually one or two seasons following the prescribed disturbance. A couple of studies (Busse et al. 2000; Laughlin et al. 2008) have documented longer term responses. Busse et al. (2000) found that shrub density was reduced for the entire 6-year study period. A striking example of the importance of following treatments for multiple years is the contrast between Fulé et al. (2002) and Laughlin et al. (2008). Fulé et al. (2002) found no significant understory response to prescribed treatments; however, a severe drought occurred during the study period and likely affected the results. Laughlin et al. (2008) performed a study in the same region, and the study period included the severe drought. Because Laughlin et al. had followed study plots for 11 years, they were able to document a decrease in production during the drought. In both Laughlin et al. (2008) and Fulé et al. (2002), plant response to treatments decreased to the same level as in controls; but after the drought, the plant response to treatments was once again positive. Clearly, weather and climate conditions can impact plant response to prescribed treatments, and environmental conditions at the time of disturbance may delay plant response. However, even studies that collect data over the short term have found that plant response is not realized until 2 years or more after treatment (Metlen et al. 2004; Wienk et al. 2004; Dodson and Fiedler 2006; Metlen and Fiedler 2006; Dodson et al. 2007; Wayman and

North 2007; Schwilk et al. 2009). In these studies, plant responses also often change from year to year. Therefore, it is important to monitor for multiple years to determine the true effects of the treatments.

Rare, threatened, and endangered species

In general, rare, threatened, and endangered species studied in the papers presented in this document responded positively to prescribed fire. Of course, many of these species are found in fire-dominated systems and were predicted to respond favorably. However, the responses varied. Some species responded immediately by resprouting and flowering, and others responded in the year after the prescribed fire (Carrington 1999). Repeated exposure to fire is required for many of these species to maintain their populations (Satterthwaite et al. 2002; Norden and Kirkman 2004; Menges et al. 2006). Late-seral species generally were not investigated in these studies, and many species not adapted to fire would be predicted to respond negatively. Therefore, it is important to manage forests in a mosaic pattern of time after disturbance, to preserve understory species of all seral stages.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

This synthesis shows that prescribed fire and mechanical thinning treatments can increase production, cover, and richness of understory herbaceous species. However, the magnitude of the response may depend on the treatment; e.g., responses generally are larger in combined treatments than in either treatment alone (Schwilk et al. 2009). Also, indicator species analyses show that different species respond to different treatments, and treatments' effects may persist over several years. Therefore, several studies suggested a mosaic of different treatments and inter-treatment intervals, to maintain diversity at a landscape level (Uresk and Severson 1998; Metlen and Fiedler 2006).

Exotic and native plant species respond in similar ways to increased intensity of disturbance. To prevent exotic plants from spreading into forest ecosystems after treatment, managers should consider several management options including the following:

- Pretreatment of exotic plants to reduce their abundance prior to treatment, and/or seeding with native plants (Korb et al. 2004)
- Reducing domestic livestock grazing before and immediately after treatment (Keeley 2006)
- Conducting a low-impact disturbance; e.g., thinning only (Dodson and Fiedler 2006; Laughlin et al. 2008)

Thinning treatments, in particular, can be modified to reduce the soil disturbance that facilitates invasion of exotic plants. Also, thinning in winter, when the ground is frozen and snow is present, will minimize soil disturbance and, thus, the probability of invasion (Gundale et al. 2005).

Exotic plants are also associated with the wildland–urban interface (WUI) because many exotics are used in landscape and horticultural plantings. Although the Healthy Forest Restoration Act (2003) mandates that most forest restoration be at the WUI, it is important to recognize that these areas serve as foci for exotic spread into the forest matrix (Bartuszevige et al. 2006); see figure 21. Exotic-plant invasion of the forest works against prescribed forest management goals to reduce wildfire risk and increase native biodiversity. Some exotic plants can change the fire interval or intensity through a variety of mechanisms, such as increasing fuel loads or fuel's moisture content (Brooks et al. 2004). In addition, exotic plants can reduce biodiversity by becoming the dominant species in the forest understory.

Exotic plants were recorded in all studies we presented but were often at a low density or cover, even after treatment. Regardless, it is important to understand the potential threat of these species to native understory species in forested landscapes. The management tools used in many of the reviewed studies were successful at increasing understory diversity and richness of both native and exotic species. In general, prescribed fire and thinning treatments can be used successfully to restore understory community composition, but managers would be wise to take into consideration the presence and potential impacts of exotic plants.

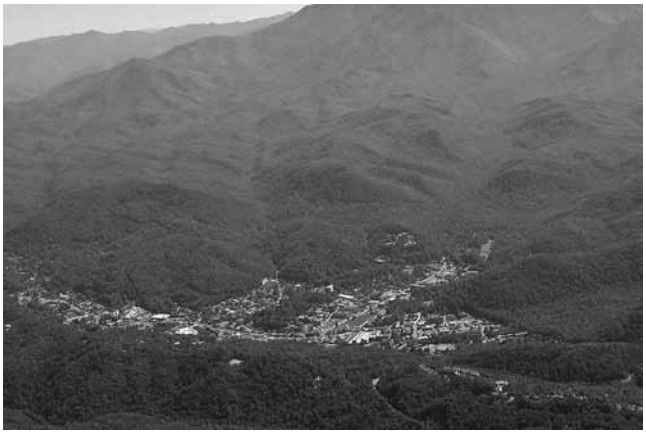


Figure 21. In recent decades, exurban development has increased the wildland–urban interface (WUI). In addition to creating many logistical constraints on fighting forest fires near these areas, the WUI can contribute to higher propagule pressure of invasive, exotic plants into the surrounding forest. (Larry Korhnak, School of Forest Resources and Conservation, University of Florida, interfacesouth.org)

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TABLES

Table 1. Selected* studies of prescribed disturbances in dry forests across the U.S., by region.

Region / Citation	Forest type	Stand age	Treatment type	N[a]	Time since fire (yr)[b]	Flame length [m (ft)]	Fire temp [°C (°F)]	Basal area remaining [m²/ha (ft²/ac)]	Sampling method[c]
Inland Pacific Northwest									
Busse et al., 2000	Ponderosa pine	Pole	Thin & Rx fire	30	1–6	0.26 (0.9)	na	na	1X1 m (3.3x3.3 ft) plots systematically located along transects
Dodson et al., 2008	Ponderosa pine / Douglas-fir	Mature	Thin & Rx fire	12	1	na	na	10–14 (43.6–61.0)	Systematically placed Whittaker plots
McConnell & Smith, 1970	Ponderosa pine	Mature	Thin	12	na	na	na	253 trees/ac 134 trees/ac 67 trees/ac 2800 trees/ac	Randomly located 4.5 m² (48.4 ft²) circular plots
Metlen et al., 2004	Ponderosa pine / Douglas-fir	60–90 yr	Thin & Rx fire	16	1	na	na	10.3–14.4 (44.9–62.7)	Systematically placed Whittaker plots
Nelson et al., 2008	Ponderosa pine	Mature	Thin & Rx fire	70	3–19	na	na	na	0.2X0.5 m (0.7x1.6 ft) plots located along transects
Youngblood et al., 2006	Ponderosa pine / Douglas-fir	70–100 yr	Thin & Rx fire	16	1	0.5–0.9 (1.6–3.0)	na	16 (69.7)	Systematically placed Whittaker plots
Central Rockies									
Dodson & Fiedler, 2006	Ponderosa pine / Douglas-fir	80–90 yr	Thin & Rx fire	12	1–3	0.2–1.2 (0.7–3.9)	na	11 (47.9)	Whittaker plot, randomly located subplots
Dodson et al., 2007	Ponderosa pine / Douglas-fir	80–90 yr	Thin & Rx fire	12	1–3	0.2–1.2 (0.7–3.9)	na	11 (47.9)	Whittaker plot, randomly located subplots
Dodson, 2004	Ponderosa pine / Douglas-fir	80–90 yr	Thin & Rx fire	12	1	0.2–1.2 (0.7–3.9)	na	11 (47.9)	Whittaker plot, randomly located subplots
Metlen & Fiedler, 2006	Ponderosa pine / Douglas-fir	80–90 yr	Thin & Rx fire	12	1–3	0.2–1.2 (0.7–3.9)	na	11 (47.9)	Whittaker plot, randomly located subplots
Uresk & Severson, 1998	Ponderosa pine	Pole & sapling	Thin	48[d]	na	na	na	37–40 (161.2–174.2) pole 27-33 (117.6–143.7) sapling	Randomly placed 30X61 cm (1x2 ft) quadrats[e]
Wienk et al., 2004	Ponderosa pine	na	Thin & Rx fire	18	1–2	0.5–1.25 (1.6–4.1)	na	12 (52.3)	Systematically placed 0.25 m² (2.7 ft²) quadrats

continues

Table 1 (continued). Selected* studies of prescribed disturbances in dry forests across the U.S., by region.

Region/Citation	Forest type	Stand age	Treatment type	N[a]	Time since fire (yr)[b]	Flame length [m (ft)]	Fire temp [°C (°F)]	Basal area remaining [m^2/ha (ft^2/ac)]	Sampling method[c]
Southern Rockies									
Covington et al., 1997	Ponderosa pine	Mature	Thin & Rx fire	15	1	na	400 (752)[f]	na	5 m (16.4 ft) diameter quadrats
Fulé et al., 2002	Ponderosa pine	na	Thin & Rx fire	4	na	0.25–1.2 (0.8–4.1)	na	na	Line intercept method
Griffis et al., 2001	Ponderosa pine	Mature	Thin, Rx fire & wildfire	16	na	na	na	18.7 (81.5) thinned 15.4 (67.1) thin+burn 31.9 (139.0) control	Systematically placed 375 m^2 (448.5 yd^2) quadrats
Laughlin et al., 2008	Ponderosa pine	Mature	Thin & Rx fire	15	1–3	na	na	na	Systematically placed 0.5X2 m (1.6x6.6 ft) quadrats
Moore et al., 2006	Ponderosa pine	Mature	Thin & Rx fire	15	1–3	0.15 (0.5)	240 (464)[f]	na	Systematically placed 0.5X2 m (1.6x6.6 ft) quadrats
Sierra Nevada									
Collins et al., 2007	Mixed conifer	na	Thin & Rx fire[g]	12	na	na	na	45.5–50.7 (198.2–220.8)	Systematically placed 400 m^2 (478.4 yd^2) quadrats
Wayman & North, 2007	Mixed Conifer	Mature	Thin & Rx fire	18	1–3	na	na	na[h]	Systematically placed 10 m^2 (107.6 ft^2) circular quadrat
Southeast United States									
Harrington & Edwards, 1999[j]	Longleaf pine	Young	Thin & Rx fire	24	1–3	na	na	na	Systematically placed 3.6 m (11.8 ft) diameter quadrats & line intercept method
Phillips & Waldrop, 2008	Shortleaf pine/ Slash pine	na	Thin & Rx fire	12	1–3	0.5–2.0 (1.6–6.6)	177–399 (350.6–750.2)[k]	18 (78.4)	Systematically placed Whittaker plots
Provencher et al., 2001[j]	Longleaf pine	na	Thin & Rx fire	24	1–3	na	na	na	Systematically placed 0.5X2 m (1.6x6.6 ft) quadrats

continues

Table 1 (continued). Selected* studies of prescribed disturbances in dry forests across the U.S., by region.

Region/Citation	Forest type	Stand age	Treatment type	N[a]	Time since fire (yr)[b]	Flame length [m (ft)]	Fire temp [°C (°F)]	Basal area remaining [m^2/ha (ft^2/ac)]	Sampling method[c]
Eastern Deciduous Forest									
Franklin et al., 2003[j]	Mixed deciduous	2nd growth	Thin & Rx fire	20–24	1–4	0.06–0.91 (0.2–3.0)	na	na	Systematically placed 3.6 m (11.8 ft) diameter plots
Waldrop et al., 2008[m]	Mixed deciduous - OH	~ 100 yr	Thin & Rx fire	12	1–4	< 1 (<3.28)	180–370 (356–698)	14 (61.0)	Systematically placed Whittaker plots
Waldrop et al., 2008[m]	Mixed deciduous - NC	80–120 yr	Thin & Rx fire	12	1–5	1–2 (3.3–6.6)	180–370 (356-698)	14 (61.0)	Systematically placed Whittaker plots
Zenner et al., 2006	Mixed deciduous	Mature	Thin	420	na	na	na	na[n]	Systematically placed 1 m^2 (10.8 ft^2) quadrats
Broad-scale patterns									
Schwilk et al., 2009	Various		Thin & Rx fire	na	na	na	na	na	Systematically placed Whittaker plots

* Studies included in the "Results" section of this document

[a] N = number of plots treated.

[b] Amount of time (years) between the prescribed fire and the data collection.

[c] Method by which understory data were collected.

[d] There were 24 pole-size stands and 24 sapling-size stands.

[e] Uresk & Severson 1998 used 0.125 m^2 (1.35ft^2) quadrats in 1981, the last year of data collection.

[f] Soil surface temperatures.

[g] At the Fire and Fire Surrogate site, thinning treatments included mastication as well as cutting.

[h] Thinning followed guidelines in the California Spotted Owl Report (Verner et al., 1992).

[j] Study included an herbicide treatment not discussed in this document.

[k] Temperature range for both the burn-only and thin+burn treatments.

[m] This paper reported results from two different Fire and Fire Surrogate sites; details from each site are reported separately.

[n] Prescription was for a 25% reduction in basal area.

Table 2. Summary of the effects of fire and thinning treatments on plant functional groups in the Inland Pacific Northwest.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Inland Pacific Northwest (Oregon)					
Forbs	Busse et al., 2000	thin+burn thin-only	Percent cover	Not significant	Not significant in either year 2 post-burn or year 5-6 postburn
Forbs	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Higher in control compared to thin-only and thin+burn	
Graminoids	Busse et al., 2000	thin+burn thin-only	Percent cover	Not significant	Not significant in either year 2 post-burn or year 5-6 postburn
Graminoids	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Not significant	
Shrubs	Busse et al., 2000	thin+burn thin-only	Percent cover	Lower cover in thin+burn plots	Result is significant in year 2 post-burn and year 5-6 postburn
Shrubs	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Higher in control and thin-only treatments compared to burn-only and thin+burn	
Inland Pacific Northwest (Washington)					
Forbs	McConnell & Smith, 1970	unthinned 67 trees/ac 134 trees/ac 253 trees/ac	Yield (lb/acre)	Not significant	
Native forbs	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Not significant	
Native forbs	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Not significant	
Non-native forbs	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Higher in thin+burn compared to burn-only	

continues

Table 2 (continued). Summary of the effects of fire and thinning treatments on plant functional groups in the Inland Pacific Northwest.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Inland Pacific Northwest (Washington)—continued					
Non-native forbs	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Thinned plots higher than unthinned plots; thin+burn plots highest richness	
Forbs	Dodson et al., 2008	control thin-only burn-only thin+burn	Species richness	Higher in thin-only and thin+burn plots compared to controls	
Forbs	Dodson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Higher cover in thin+burn plots than control	
Graminoids	McConnell & Smith, 1970	unthinned 67 trees/ac 134 trees/ac 253 trees/ac	Yield (lb/ac)	Greater yield with lower density of trees	
Native graminoids	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Not significant	
Native graminoids	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Higher in thin-only and thin+burn plots	
Non-native graminoids	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Higher in thin+burn compared to burn-only	
Non-native graminoids	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Higher in thin-only and thin+burn plots	
Graminoids	Dodson et al., 2008	control thin-only burn-only thin+burn	Species richness	Not significant	

continues

Table 2 (continued). Summary of the effects of fire and thinning treatments on plant functional groups in the Inland Pacific Northwest.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Inland Pacific Northwest (Washington)—continued					
Graminoids	Dodson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Lower cover in burn-only plots	
Shrubs	McConnell & Smith, 1970	unthinned 67 trees/ac 134 trees/ac 253 trees/ac	Yield (lb/ac)	Greater yield with lower density of trees	
Native low shrubs	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Not significant	
Native low shrubs	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Not significant	
Native tall shrubs	Nelson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Not significant	
Native tall shrubs	Nelson et al., 2008	control thin-only burn-only thin+burn	Species richness	Not significant	
Shrubs	Dodson et al., 2008	control thin-only burn-only thin+burn	Species richness	Higher in thin+burn treatments than thin-only and burn-only	
Shrubs	Dodson et al., 2008	control thin-only burn-only thin+burn	Percent cover	Not significant	

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 3. Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)						
Antelope bitterbrush	Shrub	Busse et al., 2000	thin+burn thin-only	Percent cover	Decline in thin+burn	Remained below preburn levels for entire 6-yr sample period
Arrowleaf balsamroot	Forb	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Not significant	
Arrowleaf balsamroot	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Bluebunch wheatgrass	Graminoid	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Brown's peony	Forb /	Busse et al., 2000	thin+burn thin-only	Presence / absence		Present in thin+burn plots after burning
Chaparral willowherb	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Cheatgrass	Graminoid / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Common dandelion	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Common selfheal	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Common yarrow	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Douglas' knotweed	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Elk sedge	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Decline in thin only	Highest cover values in control
Elk sedge	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Not significant	
Field brome	Graminoid / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Field pussytoes	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Fireweed	Forb /	Busse et al., 2000	thin+burn thin-only	Presence / absence		Present in thin+burn plots after burning
Geyer's sedge	Graminoid / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Heartleaf Arnica	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Houndstongue hawkweed	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Idaho fescue	Graminoid	Busse et al., 2000	thin+burn thin-only	Percent cover	Decline in thin+burn	Remained below preburn levels for entire 6-yr sample period

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Idaho fescue	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Not significant	
Idaho fescue	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Not significant	
Idaho fescue	Graminoid	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Largeleaf avens	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Largeleaf sandwort	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Lomatium species	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Longstalk clover	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Meadow deathcamas	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Miner's lettuce	Forb / Annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Narrowleaf pussytoes	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Neckweed	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Nevada pea	Legume	Busse et al., 2000	thin+burn thin-only	Presence / absence		Present in thin+burn plots after burning
Nineleaf biscuitroot	Forb	Busse et al., 2000	thin+burn thin-only	Presence / absence		Present in thin+burn plots after burning
North Africa grass	Graminoid / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Onespike danthonia	Graminoid	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Paintbrush species	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Pinegrass	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Not significant	
Pinegrass	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Not significant	
Pinegrass	Graminoid	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Pinkfairies	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Prairie junegrass	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Percent cover	Increase in thin+burn and burn-only	
Prairie junegrass	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Increase in thin+burn	Decline in control and thin-only
Prairie junegrass	Graminoid	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Prickly lettuce	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Purple oniongrass	Graminoid / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Rocky Mountain goldenrod	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Rose species	Shrub	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Sagebrush mariposa lily	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Saskatoon serviceberry	Shrub	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Smallflower miterwort	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Sticky cinquefoil	Forb	Busse et al., 2000	thin+burn; thin only	Presence / absence		Present in thin+burn plots after burning
Sticky cinquefoil	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Sticky phlox	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Stickywilly	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Sweetcicely	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Tailcup lupine	Legume	Busse et al., 2000	thin+burn; thin only	Presence / absence		Present in thin+burn plots after burning
Tailcup lupine	Legume / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Tiny trumpet	Forb / annual	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with burn-only	
Virginia strawberry	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Western needlegrass	Graminoid	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Decline in thin+burn and burn-only	Highest frequency in control

continues

Table 3 (continued). Summary of the effects of fire and thinning treatments on understory herbaceous and shrub species in the Inland Pacific Northwest (Oregon).

Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Inland Pacific Northwest (Oregon)—continued						
Western needlegrass	Graminoid / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Western showy aster	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin only	
Western stoneseed	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	
Western yarrow	Forb	Metlen et al., 2004	control thin-only burn-only thin+burn	Frequency	Not significant	
White meadowsweet	Shrub	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
White spirea	Shrub	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	
Woodland strawberry	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with control	
Wormleaf stonecrop	Forb / perennial	Youngblood et al., 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	

* Species name in **bold** indicates non-native species.

** A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 4. Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)					
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only > control = thin+burn > burn-only	1000 m^2 (0.25 ac); 2002 – 1st yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only > control	1000 m^2 (0.25 ac); 2003 – 2nd yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only > control	1000 m^2 (0.25 ac); 2004 – 3rd yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only > thin+burn > burn-only	1 m^2 (1.2 yd^2); 2002 – 1st yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > burn-only = control	1 m^2 (1.2 yd^2); 2003 – 2nd yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only > control	1 m^2 (1.2 yd^2); 2004 – 3rd yr post-treatment; burn only not significantly different from control and thin only
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Control > burn-only > thin-only > thin+burn	1000 m^2 (0.25 ac); 2002 – 1st yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m^2 (0.25 ac); 2003 – 2nd yr post-treatment
Forbs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m^2 (0.25 ac); 2004 – 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2002 – 1st yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2003 – 2nd yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2004 – 3rd yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Graminoids	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only > burn-only = thin+burn	1 m² (1.2 yd²); 2002 – 1st yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2003 – 2nd yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2004 – 3rd yr post-treatment

Shrubs	Metlen & Fiedler, 2006	control
		thin-only
		burn-only
		thin+burn
			Percent cover	Control = thin-only;
				thin-only = burn-only;
				burn-only = thin+burn;
				control > burn-only;
				thin-only > thin+burn
					1000 m² (0.25 ac);
					2002 – 1st yr post-treatment

Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Control > thin-only = thin+burn; burn-only not different from other treatments	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Shrubs	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only > control > burn-only = thin+burn	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > control = burn-only	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > control	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment; burn only not significantly different from other treatments
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > control = burn-only	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only > control	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only > control	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only > burn-only = thin+burn	1 m² (1.2 yd²); 2002 – 1st yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only = thin+burn > burn-only	1 m² (1.2 yd²); 2003 – 2nd yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only = thin+burn > burn-only	1 m² (1.2 yd²); 2004 – 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only = burn-only > thin+burn	1 m^2 (1.2 yd^2); 2002 – 1st yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only = burn-only > thin+burn	1 m^2 (1.2 yd^2); 2003 – 2nd yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Control = thin-only = burn-only > thin+burn	1 m^2 (1.2 yd^2); 2004 – 3rd yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Control > burn-only > thin+burn	1000 m^2 (0.25 ac); 2002 – 1st yr post-treatment; thin only not significantly difference from burn only and control
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m^2 (0.25 ac); 2003 – 2nd yr post-treatment
Natives	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	1000 m^2 (0.25 ac); 2004 – 3rd yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > burn-only = thin-only = control	1000 m^2 (0.25 ac); 2002 – 1st yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > burn-only = thin-only = control	1000 m^2 (0.25 ac); 2003 – 2nd yr post-treatment
Exotics	Metlen & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > burn-only = thin-only = control	1000 m^2 (0.25 ac); 2004 – 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > control = burn-only	1000 m² (0.25 ac); 2002 – 1st yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only > control; thin+burn > burn-only	1000 m² (0.25 ac); 2003 – 2nd yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only > control; thin+burn > burn-only	1000 m² (0.25 ac); 2004 – 3rd yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Not significant	1 m² (1.2 yd²); 2002 – 1st yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only = control	1 m² (1.2 yd²); 2003 – 2nd yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only = control	1 m² (1.2 yd²); 2004 – 3rd yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Not significant	2002; 1st yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	2003; 2nd yr post-treatment
Exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	2004; 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (Montana)—continued					
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin-only = thin+burn > control = burn-only	2002; 1st yr post-treatment; 1000 m² (0.25 ac);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only > control = burn-only	2003; 2nd yr post-treatment 1000 m² (0.25 ac);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only > control = burn-only	2004; 3rd yr post-treatment; 1000 m² (0.25 ac);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > control; burn-only and thin-only not different from any treatment	2002; 1st yr post-treatment; 1 m² (1.2 yd²);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > control; burn-only and thin-only not different from any treatment	2003; 2nd yr post-treatment; 1 m² (1.2 yd²);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Species richness	Thin+burn > thin-only = burn-only = control	2004; 3rd yr post-treatment; 1 m² (1.2 yd²);
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > control; burn-only and thin-only not different from any treatment	2002; 1st yr post-treatment
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	2003; 2nd yr post-treatment
Transformer exotics	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	2004; 3rd yr post-treatment

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (South Dakota)					
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop[b]	Not significant	1974 – 8 yrs postharvest; sapling size
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 23 m²/ha (100.2 ft²/ac), 28 m²/ha (122.0 ft²/ac), unthinned; 9 m²/ha (39.2 ft²/ac) > 23 m²/ha (100.2 ft²/ac), 28 m²/ha (122.0 ft²/ac), unthinned	1976 – 10 yrs postharvest; sapling size
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 23 m²/ha (100.2 ft²/ac) = unthinned	1981 – 15 yrs postharvest; sapling size; 14 m²/ha (61.0 ft²/ac) not different from other treatments
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) = 14 m²/ha (61.0 ft²/ac) = 23 m²/ha (100.2 ft²/ac) > unthinned	1974 – 8 yrs postharvest; pole size
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) = 9 m²/ha (39.2 ft²/ac) = 14 m²/ha (61.0 ft²/ac) = 23 m²/ha (100.2 ft²/ac) = 28 m²/ha (122.0 ft²/ac) > unthinned	1976 – 10 yrs postharvest; pole size

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (South Dakota)—continued					
Forbs	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 14 m²/ha (61.0 ft²/ac) > 23 m²/ha (100.2 ft²/ac) = unthinned	1981 – 15 yrs postharvest; pole size
Herbaceous dicot	Wienk et al., 2004	no-burn, no-cut; no-burn, partial-cut; burn, no-cut; burn, partial- cut	Standing crop	burn, no-cut = no-burn, no-cut; burn, partial-cut > no-burn, partial-cut; no-burn, partial-cut = no-burn, no-cut; burn, partial-cut > burn, no-cut	
Graminoids	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 23 m²/ha (100.2 ft²/ac) = unthinned	1974 – 8 yrs postharvest; sapling size; 14 m²/ha (61.0 ft²/ac) not different from any treatment
Graminoids	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac) 9 m²/ha (39.2 ft²/ac) 14 m²/ha (61.0 ft²/ac) 18 m²/ha (78.4 ft²/ac) 23 m²/ha (100.2 ft²/ac) 28 m²/ha (122.0 ft²/ac) unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 23 m²/ha (100.2 ft²/ac), 28 m²/ha (122.0 ft²/ac), unthinned; 9 m²/ha (39.2 ft²/ac) > 28 m²/ha (122.0 ft²/ac), unthinned; 14 m²/ha (61.0 ft²/ac) > 28 m²/ha (122.0 ft²/ac), unthinned; 28 m²/ha (122.0 ft²/ac)= unthinned	1976 – 10 yrs postharvest; sapling size
Graminoids	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Standing crop	5 m²/ha (21.8 ft²/ac) > 23 m²/ha (100.2 ft²/ac) = unthinned	1981 – 15 yrs postharvest; sapling size; 14 m²/ha (61.0 ft²/ac) not different from other treatments

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (South Dakota)—continued					
Graminoids	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha (21.8 ft^2/ac)= 14 m^2/ha (61.0 ft^2/ac)> unthinned	1974 – 8 yrs postharvest; pole size; 23 m^2/ha (100.2 ft^2/ac) not different from unthinned
Graminoids	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha (21.8 ft^2/ac) = 9 m^2/ha (39.2 ft^2/ac) = 14 m^2/ha (61.0 ft^2/ac) > 23 m^2/ha (100.2 ft^2/ac)= 28 m^2/ha (122.0 ft^2/ac)= unthinned	1976 – 10 yrs postharvest; pole size; 18 m^2/ha (78.4 ft^2/ac) not different from other treatments
Graminoids	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha (21.8 ft^2/ac) > 14 m^2/ha (61.0 ft^2/ac) > unthinned	1981 – 15 yrs postharvest; pole size; 23 m^2/ha (100.2 ft^2/ac) not different from 14 m^2/ha (61.0 ft^2/ac) and unthinned
Graminoids	Wienk et al., 2004	no burn, no cut; no burn, partial cut; burn, no cut; burn, partial cut	Standing crop	burn, no-cut = no-burn, no-cut; burn, partial-cut = no-burn, partial-cut; no-burn, partial-cut = no-burn, no-cut; burn, partial-cut = burn, no-cut	
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha(21.8 ft^2/ac)= 14 m^2/ha (61.0 ft^2/ac) = 23 m^2/ha (100.2 ft^2/ac) > unthinned	1974 – 8 yrs postharvest; sapling size

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (South Dakota)—continued					
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	Not significant	1976 – 10 yrs postharvest; sapling size
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	Not significant	1981 – 15 yrs postharvest; sapling size
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	Not significant	1974 – 8 yrs postharvest; pole size
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha (21.8 ft^2/ac) = 9 m^2/ha (39.2 ft^2/ac) > unthinned	1976 – 10 yrs postharvest; pole size; 14 m^2/ha (61.0 ft^2/ac), 18 m^2/ha (78.4 ft^2/ac), 23 m^2/ha (100.2 ft^2/ac), 28 m^2/ha (122.0 ft^2/ac) not different from other treatments
Shrubs	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Standing crop	5 m^2/ha(21.8 ft^2/ac) = 14 m^2/ha (61.0 ft^2/ac) = 23 m^2/ha (100.2 ft^2/ac) > unthinned	1981–15 yrs postharvest; pole size

continues

Table 4 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments[a]
Central Rockies (South Dakota)—continued					
Shrubs	Wienk et al., 2004	no-burn, no-cut; no-burn, partial-cut; burn, no-cut; burn, partial-cut	Standing crop	burn, no-cut = no-burn, no-cut; burn, partial-cut = no-burn, partial-cut; no-burn, partial-cut = no-burn, no-cut; burn, partial-cut = burn, no-cut	

[a] Metlen & Fiedler (2006) and Dodson & Fiedler (2006) measured plant responses at two different scales: 1000 m^2 (0.25 ac) and 1 m^2 (1.2 yd^2).

[b] Standing crop is measured in kg/ha (lb/ac).

* A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 5. Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)						
Autumn dwarf gentian	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Autumn dwarf gentian	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Autumn dwarf gentian	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Black hawthorn	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Blite goosefoot	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Bluebunch wheatgrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Bull thistle	Forb / biennial	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	Significant 2nd & 4th yr post-treatment
Bull thistle	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Bull thistle	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Bull thistle	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Bull thistle	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Bull thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Bull thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Bull thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Canada thistle	Forb / perennial	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	Significant 2nd & 4th yr post-treatment
Canada thistle	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Canada thistle	Forb / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Canada thistle	Forb / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Cheatgrass	Graminoid / annual	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn and control treatments	Plot scale [1000 m² (0.25 ac)]
Clover species	Forb	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Clover species	Forb	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Common dandelion	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Common dandelion	Forb / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Common mullein	Forb / biennial	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	Significant 2nd & 4th yr post-treatment
Common mullein	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Common mullein	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Common mullein	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yer post-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Common mullein	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Common mullein	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Common mullein	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Common selfheal	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Common sheep sorrel	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Common yarrow	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Common yarrow	Forb / Perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Darkthroat shootingstar	Forb / Perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Darkthroat shootingstar	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Deceptive groundsmoke	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Douglas' knotweed	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Douglas' knotweed	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Dwarf bilberry	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Field cottonrose	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant in 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Field cottonrose	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Field cottonrose	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Field cottonrose	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Field cottonrose	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species Analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Field cottonrose	Forb / annual	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn and burn-only treatments	Quadrat scale [1 m² (1.2 yd²)]
Field cottonrose	Forb / annual	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn and burn-only treatments	Quadrat scale [1 m² (1.2 yd²)]
Field cottonrose	Forb / annual	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Fireweed	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Fireweed	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Fireweed	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Fireweed	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Fireweed	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Fowl bluegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Glaucus willowherb	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Glaucus willowherb	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Holboell's rockcress	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Houndstongue	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Houndstongue	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Houndstongue	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin-only treatment	Plot scale [1000 m² (0.25 ac)]
Houndstongue	Forb / Biennial	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin-only	Significant 2nd & 4th yr post-treatment
Idaho fescue	Graminoid / Perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 1st yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Idaho fescue	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Kentucky bluegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd year post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Kentucky bluegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st & 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Kentucky bluegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Kentucky bluegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Kentucky bluegrass	Graminoid / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Kentucky bluegrass	Graminoid / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Kentucky bluegrass	Graminoid / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn and thin-only treatments	Plot scale [1000 m² (0.25 ac)]
Kinnikinnik	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Maiden blue eyed Mary	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Maiden blue eyed Mary	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Mariposa lily	Forb	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Miner's lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Miner's lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Miner's lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Miner's lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Missouri goldenrod	Forb / Perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Mountain tansymustard	Forb / Annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Narrowleaf minerslettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Nodding microseris	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale 1 m² (1.2 yd²)]
Nodding plumeless thistle	Forb / biennial	Dodson & Fiedler, 2006	control thin-only burn-only thin+burn	Indicator species analysis	Associated with thin+burn	Significant in both 2003 & 2005
Nodding plumeless thistle	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 1st, 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Nodding plumeless thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Percent cover	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 yd²)]
Nodding plumeless thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Quadrat scale [1 m² (1.2 d²)]
Nodding plumeless thistle	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Pale agoseris	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Pinegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd &3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Pinegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yrpost-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Prairie junegrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Prickly lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Prickly lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Prickly lettuce	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd &3rd yr post-treatment; at plot scale [1000 m² (1.2 yd²)]
Prickly lettuce	Forb / annual	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Prostrate knotweed	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Prostrate knotweed	Forb / annual	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Quill cryptantha	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Rocky Mountain goldenrod	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Rocky Mountain goldenrod	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Rocky Mountain goldenrod	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Rocky Mountain goldenrod	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Ross' sedge	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Rough bentgrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Rough bentgrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at quadrat scale [1 m² (0.25 ac)]
Rough bentgrass	Graminoid / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Snowbrush ceanothus	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Snowbrush ceanothus	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
Spreading fleabane	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Sticky cinquefoil	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Sticky cinquefoil	Forb / perennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Strict forget-me-not	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Sulfur cinquefoil	Forb / perennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin-only treatment	Plot scale [1000 m² (0.25 ac)]
Tall annual willowherb	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Tall annual willowherb	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Tall annual willowherb	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at quadrat scale [1 m² (1.2 yd²)]
Tall annual willowherb	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies (Montana)—continued						
White spirea	Shrub	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 1st yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Wright's cudweed	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yrpost-treatment; at plot scale [1000 m² (0.25 ac)]
Wright's cudweed	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 2nd & 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Yellow salsify	Forb / annual	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Yellow salsify	Forb / biennial	Dodson et al., 2007	control thin-only burn-only thin+burn	Indicator species analysis	Indicator of thin+burn compared to control	Pairwise comparisons of treatments to control; significant 3rd yr post-treatment; at plot scale [1000 m² (0.25 ac)]
Yellow salsify	Forb / biennial	Dodson, 2004	control thin-only burn-only thin+burn	Frequency	Increased in thin+burn treatment	Plot scale [1000 m² (0.25 ac)]
Central Rockies / South Dakota						
Alpine milkvetch	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Alpine milkvetch	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac)); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands
American red raspberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs pos-harvest; 1981 – 15 yrs postharvest; sapling-size stands
American red raspberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	higher in 9 m^2/ha (39.2 ft^2/ac) than 14, 18 m^2/ha (61.0, 78.4 ft^2/ac) and unthinned	1976 – 10 yrs postharvest; sapling-size stands
American red raspberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
American vetch	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
American vetch	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Bearded wheatgrass	Graminoid / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Bearded wheatgrass	Graminoid / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Bluebell bellflower	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Bluebell bellflower	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Bull thistle	Forb / biennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Canada hawkweed	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Canadian milkvetch	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Common dandelion	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; sapling-size stands
Common yarrow	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Common yarrow	Forb / perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Cream pea	Legume / perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	higher in 5 m²/ha (21.8 ft²/ac) than control	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Cream pea	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Creeping barberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Creeping barberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands
Creeping bentgrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands
Creeping bentgrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Field pussytoes	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Field pussytoes	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Fleabane species	Forb	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Fleabane species	Forb	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands
Goldenrod species	Forb	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Grouse whortleberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands
Hookedspur violet	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Hookedspur violet	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Inland bluegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Inland bluegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; pole-size stands
Kentucky bluegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands
Kentucky bluegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands
Kinnikinnik	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Kinnikinnik	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Kinnikinnik	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	lowest in 23 m^2/ha (100.2 ft^2/ac)	1981 – 15 yrs postharvest; pole-size stands
Lettuce species	Forb	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; sapling-size stands
Lettuce species	Forb	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands
Looseflower milkvetch	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Looseflower milkvetch	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Mountain ricegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands
Mountain ricegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands
Northern bedstraw	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Northern bedstraw	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Porter brome	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands
Prairie junegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; pole-size stands
Prairie milkvetch	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Prairie milkvetch	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Roughleaf ricegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	highest in 5 m²/ha (21.8 ft²/ac)	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; sapling-size stands
Roughleaf ricegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	highest in 5 m²/ha (21.8 ft²/ac) and 14 m²/ha (61.0 ft²/ac) than 23 m²/ha (100.2 ft²/ac) and unthinned	1981 – 15 yrs postharvest; sapling-size stands
Roughleaf ricegrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Russet buffaloberry	Shrub	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Russet buffaloberry	Shrub	Uresk & Severson, 1998	thin to: 5 m²/ha (21.8 ft²/ac); 9 m²/ha (39.2 ft²/ac); 14 m²/ha (61.0 ft²/ac); 18 m²/ha (78.4 ft²/ac); 23 m²/ha (100.2 ft²/ac); 28 m²/ha (122.0 ft²/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Saskatoon serviceberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Saskatoon serviceberry	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Sedge species	Graminoid	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	highest in 5 m^2/ha (21.8 ft^2/ac)	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Sedge species	Graminoid	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Sedge species	Graminoid	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; pole-size stands
Sedge species	Graminoid	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	highest in 5 m^2/ha (21.8 ft^2/ac), lowest in unthinned	1981 – 15 yrs postharvest; pole-size stands
Sheep fescue	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Sheep fescue	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; pole-size stands
Smooth blue aster	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Smooth blue aster	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; pole-size stands
Snowberry species	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Snowberry species	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Spreading dogbane	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Spreading dogbane	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Threenerve fleabane	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; sapling-size stands
Threenerve fleabane	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Threenerve goldenrod	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands
Threenerve goldenrod	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Timber oatgrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Timber oatgrass	Graminoid / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Twinflower	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Vetch species	Legume	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1981 – 15 yrs postharvest; sapling-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Vetch species	Legume	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Violet species	Legume	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; sapling-size stands
White clover	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
White clover	Legume / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; pole-size stands
White locoweed	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
White spirea	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
White spirea	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Woodland strawberry	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Woodland strawberry	Forb / Perennial	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands

continues

Table 5 (continued). Summary of the effects of fire and thinning treatments in the Central Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement**	Response**	Comments
Central Rockies / South Dakota—continued						
Wood's rose	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1981 – 15 yrs postharvest; sapling-size stands
Wood's rose	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	higher in 5 m^2/ha (21.8 ft^2/ac) than 18, 23, 28 m^2/ha (78.4, 100.2, 122.0 ft^2/ac) and unthinned	1976 – 10 yrs postharvest; sapling-size stands
Wood's rose	Shrub	Uresk & Severson, 1998	thin to: 5 m^2/ha (21.8 ft^2/ac); 9 m^2/ha (39.2 ft^2/ac); 14 m^2/ha (61.0 ft^2/ac); 18 m^2/ha (78.4 ft^2/ac); 23 m^2/ha (100.2 ft^2/ac); 28 m^2/ha (122.0 ft^2/ac); unthinned	Production	Not significant	1974 – 8 yrs postharvest; 1976 – 10 yrs postharvest; 1981 – 15 yrs postharvest; pole-size stands
Prickly lettuce	Forb / Annual	Wienk et al., 2004	no-burn, no-cut; no-burn, partial-cut; burn, no-cut; burn, partia-cut	Production	no-burn, no-cut = no-burn, partial-cut; burn, partial-cut > burn, no-cut; no-burn, no-cut = burn, no-cut; burn, partial-cut > no-burn, partial-cut	

*Species in **bold** are non-native species.

** A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 6. Summary of the effects of fire and thinning treatments in the Southern Rockies on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southern Rockies (Arizona)					
Native forbs	Griffis et al., 2001	control thin-only burn-only thin+burn	Abundance	Not significant	Burn-only treatment is a wildfire
Nonnative forbs	Griffis et al., 2001	control thin-only burn-only thin+burn	Abundance	Higher in burn-only treatment	Burn-only treatment is a wildfire
Native forbs	Griffis et al., 2001	control thin-only burn-only thin+burn	Species richness	Not significant	Burn-only treatment is a wildfire
Nonnative forbs	Griffis et al., 2001	control thin-only burn-only thin+burn	Species richness	Burn-only > thin+burn > thin-only = control	Burn-only treatment is a wildfire
Perennial forbs	Moore et al., 2006	control thin-only thin+burn	Standing crop	Not significant	Measured in kg/ha
Annual forbs	Moore et al., 2006	control thin-only thin+burn	Standing crop	Thin+burn > thin-only = control	Measured in kg/ha
Native graminoids	Griffis et al., 2001	control thin-only burn-only thin+burn	Abundance	Thin+burn > thin-only >control > burn-only	Burn-only treatment is a wildfire
Nonnative graminoids	Griffis et al., 2001	control thin-only burn-only thin+burn	Abundance	Not significant	Burn-only treatment is a wildfire
Native graminoids	Griffis et al., 2001	control thin-only burn-only thin+burn	Species richness	control = thin-only =thin+burn > burn-only	Burn-only treatment is a wildfire
Nonnative graminoids	Griffis et al., 2001	control thin-only burn-only thin+burn	Species richness	Not significant	Burn-only treatment is a wildfire

continues

Table 6 (continued). Summary of the effects of fire and thinning treatments in the Southern Rockies on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southern Rockies (Arizona)—continued					
Graminoids	Moore et al., 2006	control thin-only thin+burn	Standing crop	Thin-only = thin+burn >control	Measured in kg/ha
Legumes	Moore et al., 2006	control thin-only thin+burn	Standing crop	Thin-only = thin+burn >control	Measured in kg/ha

* A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 7. Summary of the effects of fire and thinning treatments in the Southern Rockies on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement	Response	Comments
Southern Rockies (Arizona)						
Arizona fescue	Graminoid / Perennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of understory thinning	
Common mullein	Forb / Biennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of prescribed burning	
Mountain muhly	Graminoid / Perennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of unburned plots	
Rusby's milkvetch	Legume / Perennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of understory thinning	
Silvery lupine	Legume / Perennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of prescribed burning	
Squirreltail	Graminoid / Perennial	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of understory thinning	
Vetch species	Legume	Laughlin et al., 2008	control thin-only thin+burn	Indicator species analysis	Indicator of understory thinning	

*Species in **bold** are non-native species.

Table 8. Summary of the results of the effects of fire and thinning treatments in the Sierra Nevada on plant functional groups.

Region (State) / Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Sierra Nevada (California)					
Forbs	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Not significant	Difference in cover post- and pretreatment
Graminoids	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Not significant	Difference in cover post- and pretreatment
Shrubs	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	control > thin-only; burn-only and thin+burn not different from any treatment	Difference in cover post- and pretreatment
Natives	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Not significant	Difference in cover post- and pretreatment
Exotics	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	thin+burn > burn-only; thin+burn > control; thin-only > control; thin-only not different from thin+burn and burn-only; control and burn-only not different	Difference in cover post- and pretreatment
Natives	Collins et al., 2007	control thin-only burn-only thin+burn	Species richness	control > thin+burn = burn-only; thin-only not different from any treatment	Difference in cover post- and pretreatment
Exotics	Collins et al., 2007	control thin-only burn-only thin+burn	Species richness	Thin+burn = thin-only > burn-only = control	Difference in cover post- and pretreatment

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 9. Summary of the effects of fire and thinning treatments in the Sierra Nevada on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement	Response	Comments
Sierra Nevada (California)						
Bedstraw species	Forb	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased 11–40% in control; decreased 11–40% in burn-only; decreased >40% in thin+burn	"evader" [a]
Big deervetch	Legume / Perennial	Wayman & North, 2007	control; no-burn+understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+overstory-thin & burn+understory-thin
Broadleaf starflower	Forb / Perennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased >40% in control and burn-only	"survivor – seed" [a]
Bull thistle	Forb / Biennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased >40% in thin-only, thin+burn, burn-only; decreased >40% in control	"colonizer – seed" [a]
Bush chinquapin	Legume / Perennial	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	most abundant in no-burn+understory-thin & burn+no-thin
Common mullein	Forb / Biennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased >40% in thin-only and thin+burn; decreased >40% in burn-only	"colonizer - seed" [a]
Coville's groundsmoke	Forb / Annual	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+overstory-thin & burn+understory- thin

continues

Table 9 (continued). Summary of the effects of fire and thinning treatments in the Sierra Nevada on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement	Response	Comments
Sierra Nevada (California)—continued						
Creeping snowberry	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Decreased 11–40% in thin-only; decreased > 40% in thin+burn and burn-only	"evader" [a]
Deerbrush	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased by 11-40% in control, thin+burn, and burn only	"colonizer - seed and resprout" [a]
Dwarf rose	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased >40% in control; increased 11–40% in thin+burn; decreased by >40% in burn-only	"survivor - seed and resprout" [a]
Greenleaf manzanita	Shrub	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Percent cover	Decreaser	most abundant in burn+no-thin & control; increased slightly in frequency
Mountain misery	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased >40% in thin-only; increased 11–40% in burn-only; decreased > 40% in thin+burn	"colonizer - root resprout" [a]
Pine violet	Forb / Perennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Decreased > 40% in thin-only and thin+burn	"evader" [a]
Pinewoods cryptantha	Forb / Annual	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+overstory-thin & burn+no-thin
Poaceae	Graminoid	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	most abundant in no-burn+understory-thin

continues

Table 9 (continued). Summary of the effects of fire and thinning treatments in the Sierra Nevada on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement	Response	Comments
Sierra Nevada (California)—continued						
Rainbow iris	Forb / Perennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Decreased 11–40% in thin+burn and burn-only	"evader" [a]
Sierra gooseberry	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased 11–40% in control; increased >40% in thin+burn	"survivor - resprout and seed" [a]
Sierra gooseberry	Shrub	Wayman & North, 2007	control; no-burn +understory-thin; no-burn +overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Percent cover	Decreaser	most abundant in burn+understory-thin & burn+overstory-thin; increased in frequency
Silver leaf phacelia	Forb / Perennial	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+understory-thin & burn+overstory- thin
Summer coralroot	Forb / Perennial	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	most abundant in control
Torrey's blue eyed Mary	Forb / Annual	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+no-thin & burn+understory-thin
Western rattle-snake plantain	Forb / Perennial	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Increased 11–40% in control; decreased >40% in thin-only, thin+burn, burn-only	"evader" [a]

continues

Table 9 (continued). Summary of the effects of fire and thinning treatments in the Sierra Nevada on understory herbaceous and shrub species.

Region (State) / Species name*	Functional group	Author citation	Treatments	Measurement	Response	Comments
Sierra Nevada (California)—continued						
White ceanothus	Shrub	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no thin; burn+understory-thin; burn+overstory-thin	Percent cover	Decreaser	most abundant in control & burn+no-thin; increased in frequency
White false gilyflower	Forb / Annual	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Increaser	most abundant in burn+understory-thin & burn+overstory- thin
White hawkweed	Forb / Perennial	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	most abundant in control & no-burn+understory-thin
Whiteveined wintergreen	Shrub	Collins et al., 2007	control thin-only burn-only thin+burn	Percent cover	Decreased >40% in thin-only, thin+burn, burn-only; decreased 11–40% in control	"evader" [a]
Whiteveined wintergreen	Shrub	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	most abundant in no-burn+understory-thin & control
Woodland pinedrops	Forb / Perennial	Wayman & North, 2007	control; no-burn+understory-thin; no-burn+overstory-thin; burn+no-thin; burn+understory-thin; burn+overstory-thin	Frequency	Decreaser	no longer present in any treatment

* Species in **bold** are non-native species.

[a] Designation provided in Collins et al., (2007). The first term indicates the plant response to disturbance and the second term indicates the proposed mechanism. One-term descriptions indicate only plant response.

Table 10. Summary of the effects of fire and thinning treatments in the Southeastern United States on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)					
Forbs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1995; treatment yr
Forbs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1996; 1st yr post-treatment
Forbs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1997; 2nd yr post-treatment
Forbs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1998; 3rd yr post-treatment
Graminoids	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1995; treatment yr
Graminoids	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1996; 1st yr post-treatment
Graminoids	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1997; 2nd yr post-treatment
Graminoids	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1998; 3rd yr post-treatment
Legumes	Provencher et al., 2001	control burn-only thin-only	Density	thin-only > burn-only = control	1995; treatment yr
Legumes	Provencher et al., 2001	control burn-only thin-only	Density	thin-only > burn-only = control	1996; 1st yr post-treatment
Legumes	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1997; 2nd yr post-treatment
Legumes	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1998; 3rd yr post-treatment

continues

Table 10 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued					
Shrubs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1995; treatment yr
Shrubs	Provencher et al., 2001	control burn-only thin-only	Density	thin-only > burn-only = control	1996; 1st yr post-treatment
Shrubs	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1997; 2nd yr post-treatment
Shrubs	Provencher et al., 2001	control burn-only thin-only	Density	thin-only > burn-only = control	1998; 3rd yr post-treatment
Vines	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1995; treatment yr
Vines	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1996; 1st yr post-treatment
Vines	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1997; 2nd yr post-treatment
Vines	Provencher et al., 2001	control burn-only thin-only	Density	Not significant	1998; 3rd yr post-treatment
Southeastern U.S. (South Carolina)					
Forbs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1994; treatment yr
Forbs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1995; 1st yr post-treatment
Forbs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	thin+burn > burn only	1996; 2nd yr post-treatment
Forbs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	thin+burn > burn only	1998; 4th yr post-treatment
Forbs	Phillips & Waldrop, 2008	control thin-only burn-only thin+burn	Abundance	burn only > thin+burn = thin only = control	change from pretreatment abundances

continues

Table 10 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (South Carolina)—continued					
Graminoids	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1994; treatment yr
Graminoids	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1995; 1st yr post-treatment
Graminoids	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	thin+burn > burn only	1996; 2nd yr post-treatment
Graminoids	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	thin+burn > burn only	1998; 4th yr post-treatment
Graminoids	Phillips & Waldrop, 2008	control thin-only burn-only thin+burn	Abundance	thin only > control > burn only; thin+burn > thin only; thin only not different from burn only or control	change from pretreatment abundances
Shrubs	Harrington & Edwards 1999	burn-only thin+burn	Percent cover	Not significant	1994; treatment yr
Shrubs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1995; 1st yr post-treatment
Shrubs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1996; 2nd yr post-treatment
Shrubs	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1998; 4th yr post-treatment
Shrubs	Phillips & Waldrop, 2008	control thin-only burn-only thin+burn	Abundance	Thin+burn > thin only = burn only = control	change from pretreatment abundances
Vines	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1994; treatment yr
Vines	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	thin+burn > burn only	1995; 1st yr post-treatment
Vines	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1996; 2nd yr post-treatment
Vines	Harrington & Edwards, 1999	burn-only thin+burn	Percent cover	Not significant	1998; 4th yr post-treatment
Vines	Phillips & Waldrop, 2008	control thin-only burn-only thin+burn	Abundance	burn only > control; thin only and thin+burn not different from any treatment	change from pretreatment abundances

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 11. Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)						
Anisescented goldenrod	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Anisescented goldenrod	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	1st yr post-treatment
Anisescented goldenrod	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	2nd yr post-treatment
Anisescented goldenrod	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Blazing star	Forb	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	Treatment yr
Blazing star	Forb	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Blazing star	Forb	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Blazing star	Forb	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Coastal plain dawnflower	Vine / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	Treatment yr
Coastal plain dawnflower	Vine / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	1st yr post-treatment
Coastal plain dawnflower	Vine / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	2nd yr post-treatment
Coastal plain dawnflower	Vine / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Coastal plain honeycombhead	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn < felling	Treatment yr
Coastal plain honeycombhead	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Coastal plain honeycombhead	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn = felling	2nd yr post-treatment
Coastal plain honeycombhead	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Dogtongue buckwheat	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Dogtongue buckwheat	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	1st yr post-treatment
Dogtongue buckwheat	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	2nd yr post-treatment
Dogtongue buckwheat	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn = felling	3rd yr post-treatment
Dwarf huckleberry	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Dwarf huckleberry	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	1st yr post-treatment
Dwarf huckleberry	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	2nd yr post-treatment
Dwarf huckleberry	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Earleaf greenbriar	Vine	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn = felling	Treatment yr
Earleaf greenbriar	Vine	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Earleaf greenbriar	Vine	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Earleaf greenbriar	Vine	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Elliott's bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Elliott's bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Elliott's bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Elliott's bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	3rd yr post-treatment
Finger rot	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	Treatment yr
Finger rot	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	1st yr post-treatment
Finger rot	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Finger rot	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Florida milkpea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	Treatment yr
Florida milkpea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	1st yr post-treatment
Florida milkpea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Florida milkpea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Fringed yellow star-grass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn < felling	Treatment yr
Fringed yellow star-grass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	1st yr post-treatment
Fringed yellow star-grass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Fringed yellow star-grass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Gopher apple	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	Treatment yr
Gopher apple	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	1st yr post-treatment
Gopher apple	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	2nd yr post-treatment
Gopher apple	Shrub	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Gray's beaksedge	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	Treatment yr
Gray's beaksedge	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	1st yr post-treatment
Gray's beaksedge	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	2nd yr post-treatment
Gray's beaksedge	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	3rd yr post-treatment
Greater Florida spurge	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Greater Florida spurge	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn = felling	1st yr post-treatment
Greater Florida spurge	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Greater Florida spurge	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Hairsedge	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	Treatment yr
Hairsedge	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	1st yr post-treatment
Hairsedge	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn < felling	2nd yr post-treatment
Hairsedge	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn < felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Little bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	Treatment yr
Little bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Little bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Little bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Littleleaf sensitive-briar	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	Treatment yr
Littleleaf sensitive-briar	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Littleleaf sensitive-briar	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Littleleaf sensitive-briar	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Mohr's threeawn	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Mohr's threeawn	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn = felling	1st yr post-treatment
Mohr's threeawn	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Mohr's threeawn	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Oak Ridge lupine	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Oak Ridge lupine	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	1st yr post-treatment
Oak Ridge lupine	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Oak Ridge lupine	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	3rd yr post-treatment
Orangegrass	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Orangegrass	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Orangegrass	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn = felling	2nd yr post-treatment
Orangegrass	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn = felling	3rd yr post-treatment
Pineland silkgrass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Pineland silkgrass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	1st yr post-treatment
Pineland silkgrass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Pineland silkgrass	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Rosette grass	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	Treatment yr
Rosette grass	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	1st yr post-treatment
Rosette grass	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	2nd yr post-treatment
Rosette grass	Graminoid	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn = felling	3rd yr post-treatment
Royal snoutbean	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	Treatment yr
Royal snoutbean	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Royal snoutbean	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Royal snoutbean	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Scurf hoarypea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Scurf hoarypea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Scurf hoarypea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	2nd yr post-treatment
Scurf hoarypea	Legume / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Splitbeard bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Splitbeard bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Splitbeard bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn < felling	2nd yr post-treatment
Splitbeard bluestem	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
St. Andrew's cross	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
St. Andrew's cross	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
St. Andrew's cross	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	2nd yr post-treatment
St. Andrew's cross	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	3rd yr post-treatment
Switchgrass	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Switchgrass	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Switchgrass	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Switchgrass	Graminoid / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn > felling	3rd yr post-treatment

continues

Table 11 (continued). Summary of the effects of fire and thinning treatments in the Southeastern United States on understory herbaceous and shrub species.

Region (State) / Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Tall jointweed	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control > burn = felling	Treatment yr
Tall jointweed	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	1st yr post-treatment
Tall jointweed	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn > felling	2nd yr post-treatment
Tall jointweed	Forb / Annual	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment
Western brakenfern	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control < burn > felling	Treatment yr
Western brakenfern	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not Significant	1st yr post-treatment
Western brakenfern	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	2nd yr post-treatment
Western brakenfern	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not Significant	3rd yr post-treatment
Whitemouth dayflower	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	Treatment yr
Whitemouth dayflower	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Control = burn < felling	1st yr post-treatment
Whitemouth dayflower	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	2nd yr post-treatment
Whitemouth dayflower	Forb / Perennial	Provencher et al., 2001	control burn felling/girdling	Density	Not significant	3rd yr post-treatment

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 12. Summary of the effects of fire and thinning treatments in the Eastern Deciduous Forest on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Eastern Deciduous Forest (Missouri)					
Forbs	Zenner et al., 2006	control; thin-only; single-tree selection; group selection	Percent cover	greater cover post-treatment in single-tree selection, group selection, and thin-only; group selection > control; thin-only and single-tree not different from other treatments	Change in relative cover
Shrubs	Zenner et al., 2006	control; thin-only; single-tree selection; group selection	Percent cover	Not significant	Change in relative cover
Vines	Zenner et al., 2006	control; thin-only; single-tree selection; group selection	Percent cover	greater cover post-treatment in all treatments; not significant among treatments	Change in relative cover
Annuals	Zenner et al., 2006	control; thin-only; single-tree selection; group selection	Percent cover	greater cover post-treatment in single-tree selection and thin-only; no differences among treatments	Change in relative cover
Eastern Deciduous Forest (North Carolina)					
Forbs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Not significant	year 1 post-treatment
Forbs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	year 3 post-treatment
Forbs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	year 5 post-treatment
Graminoids	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Not significant	year 1 post-treatment

continues

Table 12 (continued). Summary of the effects of fire and thinning treatments in the Eastern Deciduous Forest on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Eastern Deciduous Forest (North Carolina)—continued					
Graminoids	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	year 3 post-treatment
Graminoids	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Thin+burn > thin-only = burn-only = control	year 5 post-treatment
Shrubs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin-only > control = thin+burn > burn-only	year 1 post-treatment
Shrubs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin+burn = thin-only > control = burn-only	year 3 post-treatment
Shrubs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin+burn = thin-only > control = burn-only	year 5 post-treatment
Eastern Deciduous Forest (Ohio)					
Forbs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin+burn = control > thin-only; burn-only not different from any treatment	year 1 post-treatment
Forbs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin+burn = burn-only > thin-only = control	year 4 post-treatment
Graminoids	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	thin-only > control; thin+burn > control; thin+burn > burn-only; control and burn-only not different; burn-only and thin-only not different; thin-only and thin+burn not different	year 1 post-treatment

continues

Table 12 (continued). Summary of the effects of fire and thinning treatments in the Eastern Deciduous Forest on plant functional groups.

Region (State)/ Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Eastern Deciduous Forest (Ohio)—continued					
Graminoids	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	burn-only > control; thin+burn > control; thin+burn > thin-only; control and thin-only not different; burn-only and thin-only not different; burn-only and thin+burn not different	year 4 post-treatment
Shrubs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	control = thin-only > burn-only; thin+burn not different from any treatment	year 1 post-treatment
Shrubs	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Thin+burn > thin-only = burn-only > control	year 4 post-treatment

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 13. Summary of the effects of fire and thinning treatments in the Eastern Deciduous Forest on understory herbaceous and shrub species.

Region (State) /Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Eastern Deciduous Forest (Ohio)						
Greenbriar species	Shrub	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	control > burn-only = thin-only = thin+burn	year 1 post-treatment
Greenbriar species	Shrub	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	control > burn-only; contol > thin+burn; burn-only = thin+burn; thin-only = thin+burn	year 4 post-treatment
Blackberry species	Shrub	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	control > burn-only = thin-only = thin+burn	year 1 post-treatment
Blackberry species	Shrub	Waldrop et al., 2008	control; thin-only; burn-only; thin+burn	Percent cover	Not Significant	year 4 post-treatment

*A "not significant" note in the Response column indicates that none of the treatments had a statistically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

Table 14. List of citations used in this document on the effects of fire on rare, threatened or endangered plants.

Citation	Forest type	Stand age	Treatment type	N	Time since fire (yr)	Flame length [m (ft)]	Temp [oC (oF)]	Basal area left [m2/ha (ft2/ac)]	Sampling method
Franklin et al., 2006	Longleaf pine	na	Rx fire	4	1	na	na	na	Count number of stems and pollen fertilities
Harrod & Halpern, 2008	Douglas-fir	na	Rx fire	171	1–2	0.3–0.4 (1–1.3)	na	na	2X2 m (6.6x6.6 ft) plots along 50 m (164 ft) transects
Menges et al., 2006	Sand pine scrub	na	Wildfire	5	0–10	na	na	na	Randomly placed quadrats[a] along set transects
Satterthwaite et al., 2002	Turkey oak scrub	na	Rx fire	14[b]	various	na	na	na	10X10 m (131.2x131.2 ft) plots
Weekley & Menges, 2003	Sand & slash pines	na	Rx fire	31	1–2	2.4–4.6 (7.9–15.1)	na	na	Random 10X10m (131.2x131.2 ft) plots
Young et al. 2007[c]	Longleaf pine	na	na	6	na	na	na	na	20 seeds/species in each temperature
Carrington, 1999	Sand pine scrub	Mature	Rx fire	543	1–2	na	na	na	Nonrandom plots focused on plants

[a] Quadrat size = 6–84 m^2 (7.2–100.5 yd^2)

[b] Six populations had 4–14 10X10 m (131.2 x 131.2 ft) plots placed in them.

[c] Young et al. (2007) monitored reproductive ecology. They didn't burn sites; instead, they put seeds of each species into a drying oven at different temperatures and then germinated the seeds, to determine the effect of heat on germination.

Table 15. Summary of the effects of fire on rare, or threatened or endangered understory herbaceous species.

Region (State)/ Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Inland Pacific Northwest (Washington)						
Longsepal wild hollyhock	Forb / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Higher density in fall burn	Seedling density; Rattlesnake Springs site
Longsepal wild hollyhock	Forb / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Higher density in fall burn than control	Vegetative plant density; Rattlesnake Springs site
Longsepal wild hollyhock	Forb / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Not significant	Flowering plant density; all sites
Thompson's clover	Legume / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Survival	Greater survival with spring burn	Rattlesnake Grade site
Thompson's clover	Legume / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Survival	Lower survival in control	Tenas Gorge site
Thompson's clover	Legume / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Higher density in fall burn than control	Seedling density; Burch Mountain site
Thompson's clover	Legume / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Lower density in fall burn	Vegetative plant density; Rattlesnake Grade site
Thompson's clover	Legume / Perennial	Harrod & Halpern, 2008	control fall burn spring burn	Density	Not significant	Flowering plant density; all sites
Southeastern U.S. (Florida)						
Britton's beargrass	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Curtiss' milkweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Deckert's pinweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase postburn	No significance tests; +13 [a]
Deckert's pinweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase postburn	No significance tests; +24 [a]
Eastern milkpea	Legume / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +4 [a]

continues

Table 15 (continued). Summary of the effects of fire on rare, or threatened or endangered understory herbaceous species.

Region (State)/ Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Eastern milkpea	Legume / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +5 [a]
Elliott's milkpea	Legume / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Elliott's milkpea	Legume / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +1 [a]
Feay's palafox	Forb / Perennial	Carrington, 1999	burn no-burn	Flowering	Greater 19 mo postburn than 5 mo; Greater burned than no-burn	
Finger rot	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +7 [a]
Finger rot	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase postburn	No significance tests; +10 [a]
Florida alicia	Legume / Annual	Carrington, 1999	burn no-burn	Flowering	Greater burned than no-burn	
Florida alicia	Legume / Annual	Weekley & Menges, 2003	burn no-burn	Frequency	Decrease slightly postburn	No significance tests; –2 [a]
Florida alicia	Legume / Annual	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +2 [a]
Florida blazing star	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Higher survival in no-burn	
Florida blazing star	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	No change	
Florida blazing star	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Decrease slightly postburn	No significance tests; –1 [a]
Florida lady's nightcap	Vine / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Hemlock rosette grass	Graminoid / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Hemlock rosette grass	Graminoid / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No signficance tests; +1 [a]
Jeweled blue-eyed grass	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Higher survival in no-burn	
Jeweled blue-eyed grass	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Decrease slightly postburn	No significance tests; –3 [a]
Jeweled blue-eyed grass	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Decrease slightly postburn	No significance tests; –3 [a]

continues

Table 15 (continued). Summary of the effects of fire on rare, or threatened or endangered understory herbaceous species.

Region (State)/ Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Largeflower jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Higher survival in no-burn	
Largeflower jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +4 [a]
Largeflower jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase postburn	no significance tests; +10 [a]
Longleaf buckwheat	Forb / Perennial	Carrington, 1999	burn no-burn	Flowering	> 5 mo postburn than 19 mo; > burned than no-burn	
Nodding pinweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Nodding pinweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +3 [a]
Paper nailwort	Forb / Annual	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Paper nailwort	Forb / Annual	Weekley & Menges, 2003	burn no-burn	Frequency	Increase postburn	No signficance tests; +11 [a]
Paper nailwort	Forb / Annual	Weekley & Menges, 2003	burn no-burn	Abundance	Increase postburn	No significance tests; +17 [a]
Pineland scalypink	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +5 [a]
Pineland scalypink	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase postburn	No significance tests; +25 [a]
Pinescrub bluestem	Graminoid / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Sand spikemoss	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +5 [a]
Sand spikemoss	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +6 [a]
Scrub plum	Shrub	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Scrub spurge	Forb	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Scrub spurge	Forb	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +1 [a]

continues

Table 15 (continued). Summary of the effects of fire on rare, or threatened or endangered understory herbaceous species.

Region (State)/ Species name	Functional group	Author citation	Treatments	Measurement*	Response*	Comments
Southeastern U.S. (Florida)—continued						
Shortleaf blazing star	Forb / Perennial	Weekley & Menges 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Shortleaf blazing star	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +1 [a]
Showy dawnflower	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +2 [a]
Showy dawnflower	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +4 [a]
Small's jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Higher survival in no-burn	
Small's jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Frequency	Decrease postburn	No significance tests; –27 [a]
Small's jointweed	Forb / Perennial	Weekley & Menges, 2003	burn no-burn	Abundance	Decrease slightly postburn	No significance tests; –4.8 [a]
Sweetscented pigeonwings	Legume / Perennial	Weekley & Menges, 2003	burn no-burn	Survival	Not significant	Low density of plants
Wiregrass species	Graminoid	Weekley & Menges, 2003	burn no-burn	Frequency	Increase slightly postburn	No significance tests; +1 [a]
Wiregrass species	Graminoid	Weekley & Menges, 2003	burn no-burn	Abundance	Increase slightly postburn	No significance tests; +1 [a]
Southeastern U.S.						
Cobwebby wild indigo	Legume / Perennial	Young et al., 2007	control; 60°C(15.6°F); 70°C(21.1°F); 80°C(26.7°F); 90°C(32.2°F); 100°C(37.8°F)	Seed viability	60°C > 70°C = 80°C; 70°C > 90°C = 100°C	Heat shock experiment; tolerates a narrower range of temperatures for germination
Gopherweed	Legume / Perennial	Young et al., 2007	60°C(15.6°F); 70°C(21.1°F); 80°C(26.7°F); 90°C(32.2°F); 100°C(37.8°F)	Seed viability	Not significant	Heat shock experiment; not significant among treatments

*A "not significant" note in the Response column indicates that none of the treatments had a statistaically significant effect in the measure listed in the Measurement column. In most cases, significance was determined at $\alpha = 0.05$.

[a] Represents the difference between pre- and postburn abundance or frequency. No statistical tests were completed; this number is included to approximate the effect.

APPENDIX 1. SPECIES INCLUDED IN THIS SYNTHESIS

Appendix 1. Species included in this synthesis. Listing is in alphabetical order by common name.

Native / exotic*	Common name	Scientific name	Functional group
Native	alpine milkvetch	*Astragalus alpinus*	Forb
Native	American red raspberry	*Rubus idaeus*	Shrub
Native	American vetch	*Vicia americana*	Forb
Native	anisescented goldenrod	*Solidago odora*	Forb
Native	annual fescue / small six-weeks grass / small fescue	*Vulpia microstachys*	Graminoid
Native	antelope bitterbrush	*Purshia tridentata*	Shrub
Native	Arizona fescue	*Festuca arizonica*	Graminoid
Native	arrowleaf balsamroot	*Balsamorhiza sagittata*	Forb
Native	autumn dwarf gentian	*Gentianella amarella*	Forb
Exotic	**bearded wheatgrass**	***Elymus caninus***	**Graminoid**
Native	bedstraw	*Galium sp.*	Forb
Native	big deervetch	*Lotus crassifolius*	Forb
Native / exotic	**blackberry species**	***Rubus L.***	**Forb**
Native	blazing star	*Liatris Gaertn. ex Schreb.*	Forb
Native	blite goosefoot	*Chenopodium capitatum*	Forb
Native	bluebell bellflower	*Campanula rotundifolia*	Forb
Native	bluebunch wheatgrass	*Agropyron spicatum / Pseudoroegneria spicata*	Graminoid
Native / exotic	**bluegrass species**	***Poa sp.***	**Graminoid**
Native	Britton's beargrass	*Nolina brittoniana*	Shrub
Native	broadleaf starflower	*Trientalis borealis*	Forb
Exotic	**broom species**	***Cytisus sp.***	**Shrub**
Native	Brown's peony	*Paeonia brownii*	Forb
Exotic	**bull thistle**	***Cirsium vulgare***	**Forb**
Native	bush chinquapin	*Chrysolepis sempervirens*	Shrub
Exotic	**Canada thistle**	***Cirsium arvense***	**Forb**
Native	Canadian hawkweed	*Hieracium canadense*	Forb
Native	Canadian milkvetch	*Astragalus canadensis*	Forb
Native	chaffseed	*Schwalbea americana*	Forb
Native	chaparral willowherb	*Epilobium minutum*	Forb
Exotic	**cheatgrass**	***Bromus tectorum***	**Graminoid**
Native / exotic	**clover species**	***Trifolium sp.***	**Forb**
Native	coastal plain dawnflower	*Stylisma patens*	Forb
Native	coastal plain honeycombhead	*Balduina angustifolia*	Forb
Native	cobwebby wild indigo	*Baptisia arachnifera*	Forb
Exotic	**common dandelion**	***Taraxacum officinale***	**Forb**
Exotic	**common mullein**	***Verbasum thapsus***	**Forb**
Native	common self-heal	*Prunella vulgaris*	Forb
Exotic	**common sheep sorrel**	***Rumex acetosella***	**Forb**
Native	common yarrow / western yarrow	*Achillea millefolium*	Forb
Native	Coville's groundsmoke	*Gayophytum eriospermum*	Forb
Native	cream pea	*Lathyrus ochroleucus*	Forb
Native	creeping barberry	*Mahonia repens*	Shrub
Exotic	**creeping bentgrass**	***Agrostis stolonifera***	**Graminoid**
Native	creeping snowberry	*Symphoricarpos mollis*	Shrub
Native	Curtiss' milkweed	*Asclepias curtissii*	Forb
Native	darkthroat shootingstar	*Dodecatheon pulchellum*	Forb
Native	deceptive groundsmoke	*Gayophytum decipiens*	Forb
Native	Deckert's pinweed	*Lechea deckertii*	Forb
Native	deerbrush	*Ceanothus integerrimus*	Shrub
Native	dogtongue buckwheat	*Eriogonum tomentosum*	Forb
Native	Douglas fir	*Pseudotsuga menziesii*	Tree
Native	Douglas' knotweed	*Polygonum douglasii*	Forb
Native	Douglas's hawthorn / black hawthorn	*Crataegus douglasii*	Shrub

Appendix 1 (continued). Species included in this synthesis. Listing is in alphabetical order by common name.

Native / exotic*	Common name	Scientific name	Functional group
Native	dwarf bilberry	*Vaccinium caespitosum*	Shrub
Native	dwarf huckleberry	*Gaylussacia dumosa*	Shrub
Native	dwarf rose	*Rosa gymnocarpa*	Shrub
Native	earleaf greenbrier	*Smilax auriculata*	Shrub
Native	eastern milkpea	*Galactia regularis*	Forb
Native	elk sedge	*Carex garberi*	Graminoid
Native	Elliott's bluestem	*Andropogon gyrans*	Graminoid
Native	Feay's palafox	*Palafoxia feayi*	Forb
Exotic	**field brome**	***Bromus arvensis***	**Graminoid**
Exotic	**field cottonrose**	***Logfia arvensis***	**Forb**
Native	field pussytoes	*Antennaria neglecta*	Forb
Native	finger rot	*Cnidoscolus urens*	Forb
Native	fireweed	*Epilobium angustifolium / Chamerion angustifolium*	Forb
Native	fleabane species	*Erigeron*	Forb
Native	Florida alicia	*Chapmannia floridana*	Forb
Native	Florida blazing star	*Liatris ohlingerae*	Forb
Native	Florida lady's nightcap	*Bonamia grandiflora*	Forb
Native	Florida milkpea	*Galactia floridana*	Forb
Native	fowl bluegrass	*Poa palustris*	Graminoid
Native	fringed yellow star-grass	*Hypoxis juncea*	Forb
Native	garberia	*Garberia heterophylla*	Shrub
Native	Geyer's sedge	*Carex geyeri*	Graminoid
Native	glaucus willowherb	*Epilobium glaberrimum*	Forb
Native	goldenrod species	*Solidago sp.*	Forb
Native	gopher apple	*Licania michauxii*	Shrub
Native	gopherweed	*Baptisia lanceolata*	Forb
Native	grand fir	*Abies grandis*	Tree
Native	Gray's beaksedge	*Rhynchospora grayi*	Graminoid
Native	greater Florida spurge	*Euphorbia floridana*	Forb
Native	greenbrier species	*Smilax L.*	Shrub / vine
Native	greenleaf manzanita	*Arctostaphylos patula*	Shrub

Native / exotic*	Common name	Scientific name	Functional group
Native	grouse whortleberry	*Vaccinium scoparium*	Shrub
Native	hairsedge	*Bulbostylis*	Graminoid
Native	heartleaf arnica	*Arnica cordifolia*	Forb
Native	hemlock rosette grass	*Dichanthelium sabulorum*	Graminoid
Native	Holboell's rockcress	*Arabis holboellii*	Forb
Native	hookedspur violet	*Viola adunca*	Forb
Native	hound's tongue	*Cynoglossum officinale*	Forb
Native	houndstongue hawkweed	*Hieracium cynoglossoides*	Forb
Native	Idaho fescue	*Festuca idahoensis*	Graminoid
Native	inland bluegrass	*Poa nemoralis L. ssp. interior*	Graminoid
Native	jeweled blue-eyed grass	*Sisyrinchium xerophyllum*	Forb
Exotic	**Kentucky bluegrass**	***Poa pratensis***	**Graminoid**
Native	kinnikinnick	*Arctostaphylos uva-ursi*	Shrub
Native	largeflower jointweed	*Polygonella robusta*	Shrub
Native	largeleaf sandwort	*Arenaria macrophylla / Moehringia macrophylla*	Forb
Native	large-leaved avens	*Geum macrophyllum*	Forb
Native / exotic	**lettuce species**	***Lactuca sp.***	**Forb**
Native	little bluestem	*Schizachyrium*	Graminoid
Native	littleleaf sensitive-briar	*Mimosa microphylla*	Forb
Native	lodgepole pine	*Pinus contorta*	Tree
Native	lomatium species	*Lomatium utriculatum*	Forb
Native	longleaf buckwheat	*Eriogonum longifolium*	Forb
Native	longleaf pine	*Pinus palustris*	Tree
Native	jong-sepaled globe mallow / longsepal wild hollyhock	*Iliamna longisepala*	Forb
Native	long-stalk clover	*Trifolium longipes*	Forb
Native	looseflower milkvetch	*Astragalus tenellus*	Forb
Native	maiden blue eyed Mary	*Collinsia parviflora*	Forb
Native	mariposa Lily	*Calochortus spp.*	Forb
Native	meadow deathcamas	*Zigadenus venenosus*	Forb

Appendix 1 (continued). Species included in this synthesis. Listing is in alphabetical order by common name.

Native / exotic*	Common name	Scientific name	Functional group
Native	miner's-lettuce	*Claytonia perfoliata / Montia perfoliata*	Forb
Native	Missouri goldenrod	*Solidago missouriensis*	Forb
Native	Mohr's threeawn	*Aristida mohrii*	Graminoid
Native	mountain misery	*Chamaebatia foliosa*	Shrub
Native	mountain muhly	*Muhlenbergia montana*	Graminoid
Native	mountain ricegrass	*Piptatherum pungens*	Graminoid
Native	mountain tansymustard	*Descurainia incana*	Forb
Native	narrowleaf minerslettuce	*Montia linearis*	Forb
Native	narrowleaf pussytoes	*Antennaria stenophylla*	Forb
Native	neckweed	*Veronica peregrina L.*	Forb
Native	Nevada pea	*Lathyrus lanszwertii*	Forb
Native	nineleaf biscuitroot	*Lomatium triternatum*	Forb
Native	nodding pinweed	*Lechea cernua*	Forb
Exotic	**nodding plumeless thistle**	***Carduus nutans***	**Forb**
Exotic	**North Africa grass**	***Ventenata dubia***	**Graminoid**
Native	northern bedstraw	*Galium boreale*	Forb
Native	oak ridge lupine	*Lupinus diffusus*	Forb
Native	onespike danthonia	*Danthonia unispicata*	Graminoid
Native	orangegrass	*Hypericum gentianoides*	Forb
Native	paintbrush species	*Castilleja*	Forb
Native	pale agoseris	*Agoseris glauca*	Forb / Shrub
Native	paper nailwort	*Paronychia chartacea*	Forb
Native	pine violet	*Viola lobata*	Forb
Native	pinegrass	*Calamagrostis rubescens*	Graminoid
Native	pineland scalypink	*Stipulicida setacea*	Forb
Native	pineland silkgrass	*Pityopsis aspera*	Forb
Native	pinescrub bluestem	*Schizachyrium niveum*	Graminoid
Native	pinewoods cryptantha	*Cryptantha simulans*	Forb
Native	pinkfairies	*Clarkia pulchella*	Forb
Native	pitch pine	*Pinus rigida*	Tree
Native / exotic	**poaceae species**	***Poaceae sp.***	**Graminoid**

Native / exotic*	Common name	Scientific name	Functional group
Native	ponderosa pine	*Pinus ponderosa*	Tree
Native	porter brome	*Bromus porteri*	Graminoid
Native	prairie Junegrass	*Koeleria macrantha / Koeleria cristata*	Graminoid
Native	prairie milkvetch	*Astragalus laxmannii*	Forb
Exotic	**prickly lettuce**	***Lactuca serriola***	**Forb**
Exotic	**prostrate knotweed**	***Polygonum aviculare***	**Forb**
Native	purple oniongrass	*Melica spectabilis*	Graminoid
Native	quill cryptantha	*Cryptantha affinis*	Forb
Native	rainbow iris	*Iris hartwegii*	Forb
Native	Rocky Mountain goldenrod	*Solidago multiradiata*	Forb
Native / exotic	**rose species**	***Rosaceae***	**Shrub**
Native	rosette grass	*Dichanthelium*	Graminoid
Native	Ross' sedge	*Carex rossii*	Graminoid
Native	rough bentgrass	*Agrostis scabra*	Graminoid
Native	roughleaf ricegrass	*Oryzopsis asperifolia*	Graminoid
Native	royal snoutbean	*Rhynchosia cytisoides*	Forb
Native	rusby's milkvetch	*Astragalus rusbyi*	Forb
Native	russet buffaloberry	*Shepherdia canadensis*	Shrub
Native	sagebrush mariposa lily	*Calochortus macrocarpus*	Forb
Native	sand pine	*Pinus clausa*	Tree
Native	sand spikemoss	*Selaginella arenicola*	Forb
Native	Saskatoon serviceberry	*Amelanchier alnifolia*	Shrub
Native	scrub balm	*Dicerandra frutescens*	Forb
Native	scrub palmetto	*Sabal etonia*	Tree / Shrub
Native	scrub plum	*Prunus geniculata*	Shrub
Native	scrub spurge	*Euphorbia rosescens*	Forb
Native	scurf hoarypea	*Tephrosia chrysophylla*	Forb
Native	sedge species	*Carex sp.*	Graminoid
Exotic	**sheep fescue**	***Festuca ovina***	**Graminoid**
Native	shortleaf blazing star	*Liatris tenuifolia*	Forb
Native	shortleaf pine	*Pinus echinata*	Tree
Native	showy dawnflower	*Stylisma abdita*	Forb

Appendix 1 (continued). Species included in this synthesis. Listing is in alphabetical order by common name.

Native / exotic*	Common name	Scientific name	Functional group
Native	sierra gooseberry	*Ribes roezlii*	Shrub
Native	silverleaf scorpionweed / silver leaf phacelia	*Phacelia hastata*	Forb
Native	silvery lupine	*Lupinus argenteus*	Forb
Native	slash pine	*Pinus elliottii*	Tree
Native	smallflower miterwort	*Mitella stauropetala*	Forb
Native	small's jointweed	*Polygonella myriophylla*	Forb
Native	smooth blue aster	*Symphyotrichum laeve*	Forb
Native	snowberry	*Symphoricarpos albus*	Shrub
Native	snowbrush ceanothus	*Ceanothus velutinus*	Shrub
Native	splitbeard bluestem	*Andropogon ternarius*	Graminoid
Native	spreading dogbane	*Apocynum androsaemifolium*	Forb
Native	spreading fleabane	*Erigeron divergens*	Forb
Native	squirreltail	*Elymus elymoides / Sitanion hystrix*	Graminoid
Native	St. Andrew's cross	*Hypericum hypericoides*	Forb
Native	sticky cinquefoil	*Potentilla glandulosa*	Forb
Native	sticky phlox	*Phlox viscida*	Forb
Native	stickywilly	*Galium aparine*	Forb
Exotic	**strict forget-me-not**	***Myosotis stricta***	**Forb**
Exotic	**sulphur cinquefoil**	***Potentilla recta***	**Forb**
Native	summer coralroot	*Corallorhiza maculata*	Forb
Native	sweetcicely	*Osmorhiza berteroi*	Forb
Native	sweetscented pigeonwings	*Clitoria fragrans*	Forb
Native	switchgrass	*Panicum virgatum*	Graminoid
Native	tailcup lupine	*Lupinus caudatus*	Forb
Native	tall annual willowherb	*Epilobium brachycarpum*	Forb
Native	tall jointweed	*Polygonella gracilis*	Forb
Native / exotic	**thistle species**	***Cirsium sp.***	**Forb**
Native	Thompson's clover	*Trifolium thompsonii*	Forb
Native	threenerve fleabane	*Erigeron subtrinervis*	Forb
Native	threenerve goldenrod	*Solidago velutina*	Forb
Native	timber oatgrass	*Danthonia intermedia*	Graminoid
Native	tiny trumpet	*Collomia linearis*	Forb
Native	Torrey's blue eyed Mary	*Collinsia torreyi*	Forb
Native	twinflower	*Linnaea borealis*	Forb
Native	vetch species	*Vicia sp.*	Forb
Native / exotic	**violet species**	***Viola sp.***	**Forb**
Native	Virginia strawberry	*Fragaria virginiana*	Forb
Native	western brackenfern	*Pteridium aquilinum*	Forb
Native	western larch	*Larix occidentalis*	Tree
Native	western needlegrass	*Achnatherum occidentale / Stipa occidentalis*	Graminoid
Native	western rattlesnake plantain	*Goodyera oblongifolia*	Forb
Native	western showy aster	*Eurybia conspicua*	Forb
Native	western stoneseed	*Lithospermum ruderale*	Forb
Native	white ceanothus / buckbrush / California lilac	*Ceanothus cuneatus*	Shrub
Exotic	**white clover**	***Trifolium repens***	**Forb**
Native	white false gilyflower	*Allophyllum integrifolium*	Forb
Native	white fir	*Abies concolor*	Tree
Native	white hawkweed	*Hieracium albiflorum*	Forb
Native	white locoweed	*Oxytropis sericea*	Forb
Native	white meadowsweet	*Spiraea alba*	Shrub
Native	white spirea	*Spiraea betulifolia*	Shrub
Native	whitemouth dayflower	*Commelina erecta*	Forb
Native	whiteveined wintergreen	*Pyrola picta*	Forb
Native	Wiregrass species	*Aristida sp.*	Forb
Native	woodland pinedrops	*Pterospora andromedea*	Forb
Native	woodland strawberry	*Fragaria vesca*	Forb
Native	Woods' Rose	*Rosa woodsii*	Shrub
Native	wormleaf stonecrop	*Sedum stenopetalum*	Forb
Native	Wright's cudweed	*Pseudognaphalium canescens*	Forb
Exotic	**yellow salsify**	***Tragopogon dubius***	**Forb**

*Species in **bold** are exotic.

APPENDIX 2. KEYWORDS USED TO SELECT LITERATURE FOR INCLUSION

Appendix 2. Keywords used to select literature for inclusion in this document. Databases searched: Web of Science (1970 to present), Agricola (1970 to present), and Forest Science (1939 to present).

Keywords
Fire AND invasive*
Fire AND exotic*
Fire AND endanger* AND plant*
Fire AND endanger* AND specie*
Fire AND threaten* AND plant*
Fire AND threaten* AND specie*
Fire AND sensitive*
Fire AND rare
Fire AND surrogat* AND exotic*
Fire AND surrogat* AND invasive*
Burn* AND invasive*
Burn* AND exotic*
Burn* AND endanger* AND plant*
Burn* AND endanger* AND specie*
Burn* AND threaten* AND plant*
Burn* AND threaten* AND specie*
Burn* AND sensitive*
Burn* AND rare

Keywords
Thin* AND invasive*
Thin* AND exotic*
Thin* AND endanger* AND plant*
Thin* AND endanger* AND specie*
Thin* AND threaten* AND plant*
Thin* AND threaten* AND specie*
Thin* AND sensitive*
Thin* AND rare
Masticat* AND invasive*
Masticat* AND exotic*
Masticat* AND endanger* AND plant*
Masticat* AND endanger* AND specie*
Masticat* AND threaten* AND plant*
Masticat* AND threaten* AND specie*
Masticat* AND sensitive*
Masticat* AND rare

* Search included all forms of the word; e.g., both singular and plural forms (plant and plants) and past and present verb tenses (burn, burned, burning).