Chapter 3.3. Weeds, Wheels, Fire, and Juniper: Threats to Sagebrush Steppe

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Introduction

The Great Basin can be defined floristically by plant communities dominated by species of sagebrush (*Artemisia*) and saltbush (*Atriplex*) in its southern portions and in its northern portions by sagebrush steppe and woodlands dominated by juniper (*Juniperus*). By this definition, nearly 7.4 million acres (3 million ha) of Great Basin sagebrush steppe exists in the coterminous United States. It can also be defined hydrologically as the area in the Western United States that is internally drained; in other words, with a few exceptions, precipitation does not ultimately flow to the oceans, but remains in the basin (USGS 2016). The hydrologic definition is somewhat smaller in area, but important for restoration purposes (Svejcar et al. 2017). Studies clearly show that the sagebrush steppe has been in a continued state of change for many years. Portions of the Lassen and Modoc National Forests (hereafter the Lassen and the Modoc) occur in the northern portion of the Great Basin, which contains the unique Modoc Plateau subregion.

Geologic changes since the Pleistocene (about 11,700 years before present) have led to a drying-out of the area from an area of extensive wetlands and marshes to the semi-desert it is today. Beginning in the 1850s, human perturbations had significant impacts of plant community structure. But even before the gold rush of the 1850s, indigenous peoples manipulated the landscape through fire to increase food supplies and thwart enemies (McAdoo et al. 2013). The Modoc Plateau was not a particularly rich source of gold (https://www.fs.usda.gov/detail/modoc/learning/history-culture/?cid=stelprdb5310687), although the mountains to the west and south were quite productive. With dwindling forest resources near active mines, even distant mines had profound effects on woodland resources in the Great Basin. Wood was needed to fuel the mills (heating furnaces and creating charcoal) and to provide timbers to build and support the mining structures. Woodcutters were traveling more than 50 miles (80 km) to acquire the necessary trees (Morris and Rowe 2014). It was the demand for food and fresh meat to feed the booming mining towns that really opened up the sagebrush steppe for settlement (Svejcar 2015). In 1862 when the Homestead Act was signed, 160 acres (65 ha) was given to any man who could prove after 5 years that he had “improved” the land. Improvements required proof of cultivation and construction of a dwelling. Because a sustainable cattle and sheep operation was not feasible on 160 acres, the use of public, unpatented land, was extensive and on a first come, first feed basis (Morris and Rowe 2014). In 1909, the Enlarged Homestead Act increased the acres allotted to 320 acres (129 ha) and in 1916, to 640 acres (259 ha), in part as recognition that 160 acres was insufficient for livestock operations (Svejcar 2015). Although some knew, and argued, that even 640 acres was insufficient for a profitable livestock operation, and ranchers would still need open rangeland to graze their herds. One of the requirements of the 1909 Act was an increase in acres cultivated; 20 acres had to be under cultivation by the second year, and 40 acres (16 ha) from the third until the fifth and final year of the contract. This ushered in the establishment of dryland wheat cultivation, a project that the U.S. Department of Agriculture had been working on for some time (Gates 1968). And many believe it was the introduction of dryland wheat that brought cheatgrass (*Bromus tectorum*) to the Great Basin. Homesteading also increased pressure on what little woodlands were left for construction of dwellings and fences (Morris and Rowe 2014).

Homesteading and livestock ranching went through a series of booms and busts, harsh winters and unrelenting droughts in the late 1880s. By the 1890s, ranchers were rethinking 100-percent dependence on open range and began planning for cultivated hay to be used as winter feed, further expanding tillage in the Great Basin. Morris and Rowe (2014) argue that the disturbances caused by cropping exceed those caused by livestock. Management on unclaimed Federal land did not happen until 1934, when the Taylor Grazing Act was enacted. Until then, it was first come, first serve on the public lands and many acres near homesteads became clear examples of “the

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tragedy of the commons." It has been argued that what we see today on the sagebrush steppe is more a relic of the early part of the last century and less the effects of today's management. In any event, past events leave us with today's challenges in returning the sagebrush steppe to its unique ecological function.

The vast acreage of sagebrush steppe occupying the Lassen and Modoc is one of the key features that sets these national forests apart from the other national forests occupying the Sierra and Cascade ecoregions. By and large, the greatest use of these lands for human benefit is in livestock grazing. Grazing has changed natural processes and functions of the sagebrush steppe, creating both intended and unintended consequences. Some of these consequences are impacting grazing use itself. The Lassen and the Modoc completed extensive literature and resource reviews in 2010 when they each developed a Travel Management Plan (USDA 2010a, b). In addition, the Modoc's Environmental Impact Statement (EIS) for management of the sagebrush steppe ecosystem was finalized in April 2008 (USDA et al. 2008). And parts of both forests are covered by the *Science Synthesis to Support Socioecological Resilience in the Sierra Nevada and Southern Cascade Range* (hereafter, Sierra Nevada Science Synthesis) (Long et al. 2014) and the *Synthesis of Science to Inform Land Management within the Northwest Forest Plan Area* (hereafter Northwest Forest Plan Science Synthesis) (Spies et al. 2018). Because neither of these syntheses addresses the sagebrush steppe and during the last few decades ecosystem changes that reduce biodiversity and habitat suitability for several species have become a serious management problem, this chapter focuses on primary threats to the sagebrush steppe:

- Invasive weeds and loss of native grasses, forbs, and shrubs
- Surface disturbances from vehicle use
- Fire and changes to fire behavior
- Invasion by conifers.

Invasive Plant Species

Although invasive species may contribute to overall species richness in the short term, in the long run, they often cause significant decline, or even local extinction, of native plants through competition for nutrients, light, and water (Dukes and Mooney 2004) (fig. 3.3.1), as well as changes in ecosystem structure and function that can modify habitat suitability for many organisms. For example, when perennial pepperweed (*Lepidium latifolium*) invades riparian areas, it out-competes willows and cottonwood seedlings. Without these native trees, birds lose nesting sites, insects lose natural predators, and many carnivores lose a food source (Young et al. 1995).

Invasive plant species reproduce and spread rapidly. However, it often takes a disturbance event such as fire, extensive vehicle and foot traffic (including firefighting equipment), flooding, or excessive use by animals (native or wild) for invasive exotic plant species to gain a foothold. Nevertheless, because a nonnative species cannot expand its range unless it is already present on the site, early detection and rapid response to movement and introduction of seeds, rooting stems and roots pieces, or other propagules is the most important step in reducing the spread of noxious weeds (USDA 2013).

This chapter has a focus on "weeds," but the definitions for weeds used in the literature can be conflicting and confusing, and the definitions of some terms even overlap. To simplify the discussion, the term "invasive plant" is used in this chapter as defined by Presidential Executive Order 13112: "Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health a non-native species (before European settlement) within the ecosystem considered and whose introduction causes or is likely to cause economic or environmental harm (Federal Register 1999; USDA NRCS n.d.).

Numerous invasive plants, like perennial pepperweed, cheatgrass, medusahead (*Taeniatherum caput-medusae,* syn: *Elymus caput-medusae*), Dyer's woad (*Isatis tinctoria*), and various nonnative thistles have displaced native plants and altered local plant communities. Northeastern California has the highest number of species listed by the California Department of Food and Agriculture (CDFA) as noxious weeds in the State. Many weeds come into California from the Great Basin, so management strategies need to consider the regional landscape. Preventing the spread of invasive species through education and early detection are important to maintaining healthy ecosystems. Many of the conservation actions described below address prevention, early detection, and rapid response to new invasive plants to prevent them from becoming widespread. Distribution maps and summary reports for invasive plants, as well as regional strategic plans for prioritized invasive plant species, can be found on the CalWeedMapper website

Figure 3.3.1—Invasive musk thistles (*Carduus nutans*) are pretty but can quickly overrun native plant communities (Leslie J. Mehrhoff, University of Connecticut, Bugwood.org and inset photo by Joseph M. DiTomaso, Bugwood.org).

(https://calweedmapper.cal-ipc.org). Some of the invasive species affecting the province are discussed below (California Department of Fish and Wildlife 2015).

Lassen Invasive Plants

Invasive plants such as cheatgrass and mullein (*Verbascum thapsus*) are not usually tracked on the Lassen, and inventories of species such as medusahead and yellow starthistle (*Centaurea solstitialis*) are known to be incomplete (USDA 2010a). Aside from these four plant species, the Lassen internal invasive plant inventory, which serves to hone in on the most troublesome invasive plants referred to as "noxious," comprises the best available information on invasive plant distributions. According to the 2010 Travel Management Plan, the inventory is updated annually as new occurrences are found and infestations are mapped or remapped using Global Positioning System (GPS) technologies. Targeted invasive plant surveys are conducted annually in conjunction with sensitive plant surveys. They are also identified and recorded during project work. The total area infested by invasive plants on the Lassen was estimated at more than 7,000 acres (2,833 ha) in 2010, though the actual figure is likely considerably higher. The 2010 Travel Management Plan (USDA 2010a) analysis highlighted the strong association between invasive plant infestations and the current network of roads and routes open to motorized vehicle travel.

Modoc Invasive Plants

Seventeen invasive species were considered in the Travel Management Plant (USDA 2010b) analysis (table 3.3.1), but all invasive plant species identified on the forest are of concern with regard to their potential to spread and threaten native ecosystems. The Modoc, however, has prioritized invasive plant infestations for tracking based upon the aggressiveness of the species, the degree of regional concern, and feasibility of control. From the Travel Management Plan:

> *While some species listed in statewide inventories are not identified as a high priority for control efforts and are not specifically addressed in this analysis (i.e., cheatgrass, bull thistle, Russian thistle, medusahead), it remains a priority to prevent the further spread of these species via management activities. However, control of all known infestations of these lower-priority*

species is not currently feasible and they are likely to persist throughout the life of this project. A weed occurrence refers to a relatively discreet group of individuals, separated from the next nearest group of the same species by at least ¼ mile. Many of the weed occurrences are immediately adjacent to existing travel routes, due to the disturbed habitat available along the road edges, and the vehicles acting as vectors for weed seeds or other propagules. (USDA 2010b, p. 200)

While the Lassen and Modoc Travel Management Plans have some overlap in the invasive species they discuss, the Modoc plan lists eight species with a CDFA rating of "A." That rating means those species are of critical concern, subject to quarantine, eradication efforts by the State of California, and in some cases limited entry by the public into infested areas.

Weeds of Greatest Concern

Cheatgrass is perhaps the most serious invasive plant species in terms of habitat degradation for all of the Great Basin bioregion. It has infested more than 100 million acres (404,686 ha) in the Western United States (Mosley et al. 1999). By 1936, "cheatgrass lands" had become a genuine vegetation-type descriptor. Cheatgrass is highly adaptable. The typical germination pattern is a flush of seedlings in the early winter, which enables the plants to build strong root system before going semi-dormant (Young et al. 1969), however it will continue to germinate throughout the spring and summer under favorable conditions. Cheatgrass can germinate and grow under colder temperatures (Aguirre and Johnson 1991), grow faster (Concilio et al. 2015), and extract nutrients more quickly from the soil compared to native Great Basin grasses (Leffler et al. 2011; Monaco et al. 2003). At the

Table 3.3.1—Modoc National Forest noxious weed inventory. California Department of Food and Agriculture (CDFA) ratings are based on the economic threats to crops and ecosystems. An "A" rating is a serious threat requiring rapid quarantine (where appropriate) and eradication efforts. "B" and "C" ratings are systematically less serious, but still invasive plants that are capable of ecosystem harm. The California Invasive Plant Council (Cal-IPC) uses a similar system to evaluate nonnative invasive plants, but places more emphasis on natural ecosystems (table 3-69 from USDA 2010a).

Species	Common name	CDFA rating	Cal-IPC rating	Number of occurrences	Gross acres
Cardaria chalapensis	Lens-podded whitetop	B	moderate	4	9.0
Cardaria draba	Heart-podded hoarycress	B	moderate	1	0.4
Cardaria pubescens	Hairy whitetop	B	limited	2	0.2
Carduus acanthoides	Plumeless thistle	A	limited	1	0.1
Carduus nutans	Musk thistle	A	moderate	12	6.9
Centaurea diffusa	Diffuse knapweed	A	moderate	12	10.6
Centaurea stoebe ssp. *micranthos*	Spotted knapweed	A	high	13	5.1
Centaurea solstitialis	Yellow starthistle	C	high	10	2.3
Centaurea virgata ssp. *squarrosa*	Squarrose knapweed	A	moderate	5	0.2
Cirsium arvense	Canada thistle	B	moderate	34	11.9
Crupina vulgaris	Common crupina	A	limited	1	745.2
Hypericum perforatum	Klamathweed	C	moderate	8	8.8
Isatis tinctoria	Dyer's woad	B	moderate	62	6,069.9
Lepidium latifolium	Tall whitetop	B	high	1	0.1
Linaria dalmatica ssp. *dalmatica*	Dalmatian toadflax	A	moderate	12	974.7
Onopordum acanthium	Scotch thistle	A	high	333	86.5
Salvia aethiopis	Mediterranean sage	B	limited	27	11.6
Total				**539**	**7,941.2**

end of the life cycle, the dried foliage stays attached to the roots, flattening to the soil surface and creating a thatch layer that serves as both a protective mulch for the next year's crop and a barrier to germination of dicot seedlings (Stewart and Hull 1949). With time, the buildup of organic matter changes the characteristic of the soils, decreasing the edaphic suitability for native species, while favoring the spread of annual grasslands (Blank and Morgan 2012; Rimer and Evans 2006).

Once established, cheatgrass reduces rangeland forage quality for livestock (Evans and Young 1984; Hafferkamp et al. 2001). Cheatgrass can also increase economic losses when animals are injured by the spikey awns stuck in ears and eyes or have their fleece contaminated (Mealor et al. 2013) (fig. 3.3.2). The forage and habitat quality are equally poor for wildlife (Aldridge et al. 2008; Knapp 1996; Ostoja and Schupp 2009), but until recently, little incentive or funding was available for improving habitat diversity absent production agriculture. Recently, however, the relationship between cheatgrass infestations and habitat loss for greater sage-grouse (*Centrocercus urophasianus*) has increased the urgency for cheatgrass control in ecosystems (Johnson et al. 2011). Multi-State efforts are underway to improve habitat conditions for the greater sage-grouse to prevent its listing under the Endangered Species Act (USDOI 2015b; USFWS 2015; see Chapter 3.4, Dumroese, in this synthesis, *Sagebrush Rangelands and Greater Sage-grouse in Northeastern California*).

Figure 3.3.2—(A) Cheatgrass flower head (photo by Matt Lavin, University of Montana, used with permission). (B) The awns mature into prickly barbs that embed in fur and clothing, increasing distribution (photo by Pamela E. Padgett, Forest Service).

Cheatgrass originates from the Mediterranean region in Europe. Like most invasive weeds, once introduced, it had few natural pests or pathogens. Fires only enhance the competitive character of cheatgrass. Timed grazing has shown promise in reducing cheatgrass (Diamond et al. 2009). But grazing is only successful in the early season, when the blades are palatable, and it requires careful planning and control as overgrazing will contribute to cheatgrass spread (Mealor et al. 2013; Tzankova and Concilio 2015; see Chapter 3.2, Dumroese, in this synthesis, *Rangeland in Northeastern California*). In small areas, hand removal prior to seed production is often successful in greatly reducing the population, but the approach is not appropriate to large open wildlands (Concilio 2013). Several herbicide treatments specific for annual grasses and broad spectrum are available. Imazapic, a grass-specific pre- and post-emergent herbicide most commonly used in Idaho, Wyoming, and Nevada for cheatgrass control is not available in California. Other grass-specific herbicides are expensive, controversial, and difficult to use across large landscapes (Tzankova and Concilio 2015). Although a broader array of herbicides targeting broadleaf weeds that spare monocots is available, unintended consequences of their use, particularly in shrublands, can be dire. One study looked at the longevity of the effects of the broadleaf herbicide picloram in an effort to restore native grasslands. The aim was to test the hypothesis that temporary reductions of weedy forbs would allow native grasses to gain and foothold and out compete subsequent infestations. The results showed that within 4 years and certainly by 16 years, the returning weeds were well established and the native grasses had reduced abundance (Rinella et al. 2009).

Cheatgrass's Achilles heel of low seed durability makes the elimination of mature plants before they produce seeds a potential option to greatly reduce populations. Two types of biocides seem to hold some promise for long-term control: a fungal pathogen, *Pyrenophora semeniperda* developed by Dr. Susan Meyer (U.S. Department of Agriculture, Forest

Service, Rocky Mountain Research Station; Meyer et al. 2007), and a bacterial pathogen *Pseudomonas flourescens* isolated and developed by Dr. Ann Kennedy (Ibekwe et al. 2010). Both inhibit seedling germination and have been shown to be effective in greenhouse studies and field studies. *Pseudomonas flourescens* is a widely dispersed bacteria found in nearly every soil type. *Pyrenophora semeniperda* is also widely dispersed, but oddly not found in *B. tectorum's* native habitat.

Yellow starthistle is a CDFA C-rated pest, which means that it is a medium to low threat to agriculture or the ecosystems. A member of the Asteraceae family, this winter annual establishes during fall and winter and flowers the next year. This species reproduces primarily by seeds, persists at high population densities, and is associated with disturbance such as grazing, fire, and road construction. The seeds of yellow starthistle may persist in the soil for up to 10 years (Zouhar 2002). This species is widespread on the western, low-elevation portions of the Lassen. Small infestations are usually treated by hand pulling. No economically effective chemical treatments for larger infestations are available that do not harm desirable plant species.

Yellow starthistle occurs throughout the arid and semiarid regions of the West. It is highly adaptable and can rapidly take over landscapes, particularly after disturbances, creating dense stands and decreasing biodiversity. It is unpalatable, even toxic, to livestock and provides very poor habitat for wildlife. *The Field Guide for Managing Yellow Starthistle in the Southwest* (USDA 2014a) has compiled the most recent integrated pest management approaches for controlling this weed. Early detection and eradication of small patches is the best approach, as highly infested areas may take 3 or more years to clear. Because starthistle reproduces only by seeds. Control methods should be focused on removing the plants before they set seeds. Prescribed fire and grazing have been evaluated as possible control mechanisms. Neither is particularly effective alone. Often the plants do not produce enough dry fuel to carry a fire of the intensity needed to kill seeds in the spring and early summer, before the plants start blooming. On one hand, grazing by horses and cattle is not particularly effective because once the plants start flowering, the spines on the flower heads become unpalatable, and even dangerous; thus, grazing using most livestock must be carefully managed. Goats, on the other hand, have been effective if managed for short, intensive grazing with frequent moving. Both chemical and biological control agents are available (refer to the most recent California registered pesticide website: www.cdpr.ca.gov/docs/label/labelque.htm). The biological controls work by reducing seed production (Wilson et al. 2003). Because starthistle can produce millions of seeds per acre, however, the effectiveness of control can take many years in large infestation. Herbicides are most effective when applied at the early growth stages. The most effective strategies combine herbicides with grazing and/or fire.

Pepperweed is a CDFA B-rated weed, which means that it is a medium to high threat to agriculture or ecosystems, but is fairly limited in distribution. It is a perennial forb in the family Brassicaceae. This species is a high priority for control on the Lassen, as it has the potential to severely degrade riparian sites by crowding out native vegetation. Though most of these occurrences consist of fewer than 25 stems, perennial pepperweed has been difficult to eradicate due to this species' ability to form new shoots from buds on lateral, creeping roots (DiTomaso et al. 2013).

Perennial pepperweed is a forb that usually reproduces vegetatively rather than by seeds. Among its adaptations is "salt pumping"—the ability to absorb ions (particularly sodium and magnesium) from deep in the soil profile and release them at the soil surface, effectively creating a saline soil layer on the surface, thus reducing the ability of native plants to germinate and repopulate (Renz and Blank 2004). Pepperweed occurs in every county in California and every Western State, even extending into New England. It tends to be a more serious pest in riparian and seasonally wet areas. Individuals can grow to be 6 feet (2 meters) tall. Like all invasive plants, infestation of pepperweed crowds out native plant species and reduces fauna biodiversity. Several guidebooks and fact sheets for control have been published in the last few years, including the *Forest Service Field Guide for Managing Perennial Pepperweed in the Southwest* (USDA 2014b). Most mechanical methods, such as mowing and discing, are not recommended because pepperweed has an extensive root system that allows mowed plants to quickly resprout, and root segments as small as 1 inch generated by plowing can survive long periods of desiccation and quickly grow into new plants when moisture becomes available. Fire is also known to increase pepperweed infestations, although both fire and mowing can be used to remove top growth prior to chemical treatments. Grazing has been tested as a control mechanism with some success, particularly the use of sheep and goats. And in areas where chemical control may be undesirable, such as vernal pools (Vollmar

Consulting AECOM 2009). However, the plants become unpalatable once flower heads are formed. Some evidence suggests this plant is toxic to horses when consumed in large quantities (Young et al. 1995). Interestingly, dodder (*Cuscuta subinclusa*), preferentially colonizes pepperweed and reduces seed weight and germination of pepperweed by 27 and 42 percent, respectively (Benner and Parker 2004). Dodder itself can, however, become a serious invasive pest.

Oxeye daisy (*Leucanthemum vulgare*) is not rated by CDFA, but is inventoried on the Lassen. This species, in the family Asteraceae, may reproduce vegetatively from shoots that develop from buds on lateral roots in addition to seeds. It was introduced as an ornamental and is still sold commercially in seed packets (Cal-IPC 2018). It is well adapted to many environments from open fields to woodland and can be a significant problem in riparian corridors. Oxeye daisy is a prolific seeder, and seeds remain viable for many years in the soil. Available information indicates that priority for treatment is given to new, small infestations that may be successfully decreased or eradicated with repeated manual treatments.

Medusahead is a CDFA C-rated noxious grass in the family *Poaceae*. This species is highly competitive and may form monotypic stands where it occurs. This grass is unpalatable to livestock and produces a prolific amount of seeds annually. Successful suppression usually involves some combination of herbicide, fire, and reseeding with other grass species (Archer 2001). As with yellow starthistle, inventories within this area are incomplete, and the more than 2,000 acres (809 ha) that this species is known to occupy within the project area is likely a significant underestimate. When infestation cannot be effectively treated with manual control strategies, no economically effective chemical treatments are available for larger infestations that do not harm desirable plant species.

Medusahead has a similar life history to cheatgrass. It, however, is a more recent introduction. It germinates in the fall and winter, growing strong root systems before the shoots expand in the spring. Like cheatgrass it is an annual; once the seeds ripen, the shoots die, leaving a dense thatch that can choke out germination of native plants and provide a fuel layer for fire (fig. 3.3.3). Mowing, discing, grazing, and prescribed fire can be effective means of control. As with most annual invasive plants, conducting control measures before the plants set seeds and shatter is critical

Figure 3.3.3—Medusahead litter with emerging seedlings (photo by Thomas Getts, University of California Agriculture and Natural Resources, used with permission).

to successful eradication. Unlike cheatgrass, no biological controls have been found, although efforts to find and develop them continue.

Scotch thistle (*Onopordum acanthium*) is a CDFA-A-rated weed. Originally introduced in the late 1900s as a horticultural ornamental, it is still grown in gardens today. Scotch thistle is typically a biannual, but individuals can persist for several years. During the first year, plants present as low-growing rosettes. In the second year, the stems grow to their full height and the plants flower, creating seeds for expansion of populations. Severe infestations can form tall, dense, impenetrable stands, especially in fertile soils. Like most weeds, it gets a foothold in disturbed areas, but can rapidly spread into natural areas, especially into particularly fertile soils. Chemical control of this thistle is difficult because of its ability to germinate nearly year-round, requiring multiple herbicide applications. Herbicides are effective on first-year seedlings, but once the stem begins to elongate, chemical control loses its effectiveness. Research has demonstrated certain requirements for Scotch thistle seed germination, providing some possible management strategies that may reduce expansion of populations. The achene coat must be leached prior to germination due to a water-soluble inhibitor on the seed surface. Seed germination is much higher when seed/soil contact is maximized, and seeds require light to germinate.

Knapweeds (*Centaurea* species) are CDFA-A rated. Diffuse (*C. diffusa*), sparrose (*C. virgata*), and spotted (*C. stoebe* ssp. *micranthos*) are the most common. Drought and fire resistant, knapweeds produce allelopathic effects and are highly competitive with other plants, often displacing desired vegetation. Knapweeds are now found in all United States and much of Canada. *Centaurea* is a large genus comprised of about 500 species, none native to California. Most species are highly prolific in disturbed areas and once infested, can be very difficult to eradicate. Like nearly all invasive plants, eradication of knapweeds requires time and a carefully planned multifaceted management approach (DiTomaso et al. 2013). Spotted knapweed is particularly invasive, as it reproduces not only by seed but also vegetatively from lateral roots. New plants can develop at about 1.25-inch (3-cm) intervals along the lateral roots, expanding populations peripherally. Diffuse knapweeds are often spread by a "tumbleweed strategy." At maturity, the stems separate from roots and the entire plant is tumbled around by the wind, dispersing seeds over potentially long distances. Once established, eradication of all knapweeds is challenging. Most species have stout taproots that readily resprout unless entirely removed. In ecologically sensitive areas, eradication by hand removal is possible, but may take two or three treatments per year for multiple years. Control and management require an integrated approach. Herbicides can reduce seedling numbers, but knapweeds are prolific seeds, and germination can occur throughout the year when conditions are favorable. Grazing may be helpful in the early season, but soil disturbance from hooves can provide ideal seedbeds. Fire generally is not very effective unless the fire intensity is high and heat penetrates well into the soil profile to kill seeds and roots. Several herbicides are effective in controlling knapweeds. Application timing is critical to the success; most are effective during the early stages of growth. Montana has introduced 13 insect species for control of spotted and diffuse knapweeds with good results (Duncan et al. 2017), and several projects are underway in California (CDFA 2018).

Figure 3.3.4—Cheatgrass has been observed invading along roads in arid shrubland environments. It is often the first plant to germinate in early spring, which gives it a competitive advantage over later-germinating native plant seedlings (photo by Pamela E. Padgett, Forest Service).

Vehicles

Vehicles can be disturbance sources, damaging native plants and allowing invasive plant populations to expand (fig. 3.3.4). They can also be vectors for invasive plants, serving as a transport mechanism for moving invasive species seeds and other propagules into pristine areas, resulting in new infestations. Vehicles are generally interpreted as motorized personal conveyances, but bicycles, construction equipment, and even aircraft can unknowingly carry noxious hitchhikers into the back country. There is, unfortunately, very little experimental or scientific data supporting the somewhat intuitive notion that vehicles are vectors for seed dispersal. Observations, however, frequently show that weedy infestations are densest near trails and roads (Usher 1988). One small study counted the number of seeds found on visitors (mostly shoes) to a park in South Africa. The 68 participants fell into three categories: hikers, cyclists, and dog walkers. Dog walkers (but not the dogs) were found to carry the most nonnative seeds, followed by hikers, the shoes of cyclists, then dogs. None of the bike tires carried seeds (Bouchard et al. 2015). A modeling study testing relative importance of potential seed vectors was conducted by Brancatelli and Zalba (2018). The study used several variables including the physical characteristics of seeds that effect transport, potential volume of seeds any one vector could transport, and control and impact of the particular species. Cargo carried into a protected site was found to have the highest potential for introduction of alien plant species, followed by vehicles.

The Travel Management Plans completed by the Lassen and the Modoc in 2010 did a thorough job of analyzing the issue of standard vehicle travel and damage to sagebrush steppe. Once the preferred alternatives were adopted, off-road traffic, and even use of graveled roads, is generally prohibited by the Travel Management Plans, although exceptions are made for ranchers and hunters whose legislatively permitted activities require access to remote areas. It is expected that the reduction in off-road activity and the reduction in road access in general will reduce physical disturbance to soil surfaces, and thus reduce the opportunities for existing weed populations to expand (see also *Impacts of Energy Development and Vehicles* in Chapter 4.3, Dumroese, this synthesis, *Sagebrush Rangelands and Greater Sage-grouse in Northeastern California*). The next step is to ensure that vehicles (including bicycles and aircraft) are weed-free prior to entering the back country, as recommended by regional guidelines. The *USDA Forest Service Guide to Noxious Weed Prevention Practices* (USDA 2001) has basic guidelines in managing equipment going in and out of the field, and although a bit dated, should be standard operating procedures for all staff, contractors, ranchers, and recreationists.

Fire

Fire is a natural component of the sagebrush steppe (fig. 3.3.5). The history and current status of fire in the sagebrush steppe has been well described by Ellsworth and Kauffman (2017) and Riegel et al. (2006). Empirical data regarding fire-return intervals before settlement in sagebrush steppe is limited, but estimates of 15 to 25 years before human activities are typical (Miller and Rose 1995). However, natural fire-return intervals are influenced by moisture gradient. In dryer areas, such as south-facing slopes where evapotranspiration is high and overall vegetation productivity is low, juniper (*Juniperus*) trees older than 50 years are common. While on the more productive adjacent slopes where evapotranspiration is lower due to lower solar radiation, older junipers are usually absent, but vegetation cover is denser. Fire ecologists use this relationship between moisture, vegetation density, and fire behavior on physically adjacent landscapes to deduce fire-return intervals absent human influences. The reasoning follows: because junipers are more resistant as they age (50 years being a commonly

Figure 3.3.5—Fire is a natural component of the sagebrush ecosystem and is one of the most common tools used to restore them. Prescribed fire is used to replace wildfires that would naturally keep sagebrush stands from becoming invaded by conifers that reduce the perennial grass and forb components (photo by Kenneth O. Fulgham, Regents of the University of California, used with permission).

noted age), the absence of older trees suggest that fire-return intervals on productive soils, pre-European settlement, may have been 50 years or less. In contrast, less-productive areas with lower fuels loads may not experience crown-killing fires for 100 years or more (Riegel et al. 2006; Rimer and Evans 2006). See Chapter 2.1 (Moser, this synthesis, *Understanding and Managing the Dry Conifer Forests of Northeastern California*) for additional discussion.

In modern times, the changes in fuel loading, particularly invasions of weedy grasses, is arguably the most serious problem in increased fire rates. Dried foliage is easily ignited and often provides a continuous mat of flammable fuel that accelerates fire spread (Stewart and Hull 1949). After fire, native plants are slow to recruit and grow, allowing cheatgrass, among others, to dominate the landscape (Stewart and Hull 1949). The presence of cheatgrass and other annual grasses has changed the fire regimes in many areas (Brooks et al. 2004; D'Antonio and Vitousek 1992). Lightning strikes are frequent in the sagebrush steppe (van Wagtendonk and Cayan 2008). Under pristine conditions, a lightning strike may initiate a fire, but with little understory fuel, the fire is restricted to a small area, as is consistent with the patchy nature of shrublands and woodlands. When grasses occupy the understory, a lightning strike can become a conflagration as fire spreads from shrub and tree patches on corridors of grass tinder. Thus, cheatgrass can increase both the frequency and extent of fire, with high associated costs for public land managers (Borman 2000; National Interagency Fire Center 2013).

The recovery of native shrubs following fire depends on several variables (Ellsworth and Kauffman 2017), among them, the general health of the individual and the age. Antelope bitterbrush (*Purshia tridentata*) and curlleaf mahogany (*Cercocarpus ledifolius*), important browse for wildlife, rarely resprout when younger than 5 years or older than 20 to 40 years (Martin and Driver 1983). Most of the sagebrush species are highly susceptible to fires (Hanna and Fulgham 2015). Except for silver sagebrush (*Artemisia cana*), regrowth after fire is seed-dependent. After large high-intensity fires, recolonization by sagebrush can be slow if few seeds are left unburned and mature plants with viable seeds are far away.

In 2015, the Secretary of the U.S. Department of the Interior (DOI) issued *Secretarial Order 3336 – The Initial Report* (USDOI 2015a) that highlighted the need to change the way fires were managed on rangelands, particularly on rangelands occupied, or once occupied, by sage-grouse (*Centrocercus* spp.). The order required actions by many DOI agencies and required that DOI work cooperatively and collaboratively with other Federal agencies, States and tribes, and stakeholders to develop an "enhanced fire prevention, suppression, and restoration strategy."

Conifer Encroachment

Changes in fire regime and grazing have contributed to extensive conifer encroachment into the sagebrush ecosystems (fig. 3.3.6), reducing habitat for greater sage-grouse (*Centrocercus urophasianus*) and grazing opportunity for livestock (Burkhardt and Tisdale 1969; Miller and Wigand 1994; Miller and Rose 1995). Throughout the Great Basin, this encroachment is often a mixture of juniper and Jeffrey and ponderosa pines (yellow pines; *Pinus jeffreyi* and *P. ponderosa*) (see Chapter 2.1, Moser, this synthesis, *Understanding and Managing the Dry Conifer Forests of Northeastern California*, for a robust discussion on juniper woodlands in the West, their ecology and dynamics, and management). This chronic, relentless encroachment, and its impacts on wildlife, have been observed for decades. Loft (1998) writes *"Northeastern California has recently been identified as a focus area for deer habitat management efforts on public lands in California where the objective is to improve habitat conditions (Loft et al. 1998). Deer populations and deer habitat conditions have declined significantly in recent decades. Deer populations in the area were estimated at 160,000, 130,000, and 35,000 in 1949, 1992, and 1996, respectively (Longhurst et al. 1952, Loft et al. 1998). Since 1957, overstory canopy of juniper and pine has increased by over 400 percent on some key bitterbrush ranges, thereby crowding and shading out of desirable browse (CDFG unpubl. data 1998)."*

The scale of encroachment puts pressure on limited resources. Greater sage-grouse are particularly sensitive to conifers. Data suggests that increases in conifer cover as small as 4 percent eliminate breeding leks from once active areas (Severson et al. 2017). Other than an increase in the available literature supporting the need for conifer removal in support of expanding greater sage-grouse habitat, no new papers contain substantial new methods for management of conifer woodlands. See Chapter 3.2 (Dumroese, this synthesis, *Rangeland in Northeastern California*) for restoration techniques of sagebrush rangelands, including conifer removal.

Figure 3.3.6—Western junipers (*Juniperus occidentalis*) are native and an important component of the Great Basin plant community, but they can also be invasive, replacing shrublands with woodlands. Juniper encroachment is a problem for greater sage-grouse habitat (stock photo purchased from alamy.com).

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