Annotated bibliography of scientific publications on medusahead (*Taeniatherum caput-medusae*) 2000-2019: Relationship with fire and response to fire and other control methods

Table of Contents

Innes, Robin J. 2019. Annotated bibliography of scientific publications on medusahead 2000-2019: relationship with fire and response to fire and other control methods. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory (Producer). Available: https://www.fs.usda.gov/database/feis/plants/graminoid/taecap/annbib/all.html

Introduction

This annotated bibliography is intended to supplement the Fire Effects Information System's (FEIS) Species Review about medusahead [1] and provide a summary of more recently published information about medusahead's relationship with fire and response to fire and other control methods in wildlands.

Methods

I searched the FEIS Citation Retrieval System, Google Scholar, JSTOR, ProQuest Dissertations and Theses Global, and Web of Science reference databases for studies on medusahead (*Taeniatherum caput-medusae* and its synonyms) published between 1999 and 2019. From these search results, I selected literature reviews and syntheses, primary research articles in peer-reviewed journals and proceedings, books, formal reports, dissertations, and theses in which medusahead's fire ecology or response to control methods in wildlands was a research focus. I examined similar publications cited within these publications to expand my search. I excluded studies cited within the FEIS Species Review and studies conducted outside of North America, except those on biological control agents that were applicable to medusahead management in North America.

I provided a summary of medusahead's biology, fire ecology, management considerations, and control methods based on literature reviews and syntheses. I compiled the primary research publications about medusahead's response to fire, and provided details on study sites, control methods tested, and main findings related to medusahead (table 1). I also compiled publications about medusahead's response to control methods other than fire, and provided details on study sites and control methods tested (table 2). Common and scientific names of plants mentioned in this annotated bibliography are listed in table A1, with links to FEIS Species Reviews, if available.

Results

I found 24 studies published between 2000 and 2019 that provided data on medusahead's response to fire (sometimes in combination with other control methods). Table 1 summarizes the results of these studies. Most of these studies (*n* = 15) report medusahead response <3 years after fire. Although medusahead occurs in seven western states [86], fire studies were conducted only in California (*n* = 11), Oregon (*n* = 12), Idaho (*n* = 1), and Utah (*n* = 1). Study locations were in plant communities where medusahead has been most invasive: sagebrush-steppe in the Intermountain West (*n* = 16), and annual grasslands and oak woodlands in western California and Oregon (*n* = 9). One study occurred in both California and Oregon [43] and another study occurred in both annual grasslands and sagebrush-steppe [46]. In addition to these 24 studies, a systematic review and meta-analysis of control effects on medusahead was published in 2015 [40], and five syntheses addressing medusahead fire ecology and/or management were published from 2006 to 2014 [32, 35, 36, 41, 57]. The following Summary of Medusahead Ecology and Fire Management Considerations is based primarily on these six publications and the FEIS Species Review [1].

I found 56 studies that provided data on medusahead's response to control methods other than fire. See the section on Other Management Considerations and table 2 for details.

Summary of Medusahead Ecology and Fire Management Considerations

General

Medusahead is a nonnative, cool-season annual grass that is invasive in many sagebrush-bunchgrass or bunchgrass communities below 1,370 m in the Intermountain West and in annual grassland or oak woodland communities in valleys and foothills of California and Oregon. Medusahead invasion reduces biodiversity, wildlife habitat, and forage production, and may lead to increased fire frequency and restoration costs [1, 41, 45, 57].

Biology and Ecology

Medusahead occurs in areas with hot, dry summers where average annual precipitation ranges from 250 to 1,000 mm, although it is more typically found on sites where average annual precipitation ranges from 300 to 610 mm [45]. It is most invasive on clay soils; however, invasion potential increases with disturbance to soils and removal of native vegetation on all soil types [1, 57]. Medusahead reproduces by seed, and seed production can be abundant [1, 35, 57]. For example, a stand of medusahead can produce >10,000 seeds/m^2 [57]. Flowering occurs in spring (typically early June) and most seeds are mature by late June to early July [1, 45, 57]. Seed dispersal begins in late summer (mostly August) and continues into fall. Seeds usually disperse no more than 2 m from parent plants, although some may be dispersed longer distances by animals and humans [41, 45, 57]. Most seeds in soil seed banks appear to germinate or lose viability within 2 years [35, 45]. Germination typically occurs in fall (October to November) and can continue into winter and spring [35, 41, 45, 57]. Germination and seedling establishment are best on sites with litter on the soil surface [1]. Medusahead grows slowly in fall due to cool temperatures. Growth continues in fall until cold weather stops growth. A period of rapid growth begins in spring due to warm temperatures. Root growth can continue throughout winter and accelerates in spring [1, 41, 45, 57].

Fire Ecology

Fire kills medusahead plants and most seeds in seedheads and litter, but some seeds in the soil seed bank likely survive fast-moving grass fires. Plants that establish after fire may produce large numbers of seeds, and medusahead abundance may reach prefire levels within a few postfire years [1]. Medusahead produces long-lasting, highly flammable litter that decomposes slowly and can form a dense thatch layer in invaded areas. This can limit germination and establishment of native vegetation and increase the amount and continuity of fine fuels, which could increase the likelihood and severity of fire in shrub-steppe ecosystems [1, 45, 57] (figure 1). Fire that either kills seeds in seedheads or kills the plant before seeds mature can reduce medusahead abundance in the short term [31, 32, 57]. In the long term, medusahead often occurs and may be abundant in burned areas [63] and wildland fire fuel breaks [52].

Figure 1. Medusahead produces long-lasting, highly flammable litter that can form a dense thatch layer in invaded areas. Image courtesy of Matt Lavin, Wikimedia Commons.

Fire Management Considerations

Fire management considerations for medusahead differ among sites, partly due to differences in plant community species composition, phenology, and fire ecology. In annual grasslands in foothills and valleys of western California and Oregon, fire may reduce medusahead abundance and promote desirable species, while in perennial grasslands and shrublands in the Intermountain West, fire may injure or kill desirable bunchgrasses, shrubs, and forbs, creating opportunities for medusahead establishment and spread [40, 45, 57]. A systematic review and meta-analysis of 22 studies on the effects of prescribed fire, herbicides, livestock grazing, and seeding desirable species on medusahead abundance (cover, biomass, and density) found that most treatments reduced medusahead abundance in the first year in both annual and perennial grasslands and shrublands, but reductions from burning did not last beyond the first postfire year. While burning was not combined with other control methods in annual grassland studies, the duration of control did not increase when burning was combined with seeding and/or herbicide treatments in perennial grasslands and shrublands, although studies of postfire responses were limited [40]. See table 1 for information on medusahead response to fire with and without other treatments in specific locations.

In California annual grasslands, prescribed fire can be timed to decrease medusahead abundance without reducing desirable plants [31, 35, 57]. However, even a properly timed fire may increase other undesirable plants, such as stork's bill [32]. Medusahead produces and disperses seeds later than many associated annual species. This provides a window when fuels are cured enough to carry fire, viable medusahead seeds are still in seedheads where they are easily killed by fire, and seeds of desirable species have dispersed to the soil surface where they are more likely to survive [31, 32, 35, 45]. Slow-moving, intense fires kill the greatest number of medusahead seeds [1, 32]. However, medusahead seeds on the soil surface may still survive in sufficient quantities to recolonize a site. Therefore, multiple fires in consecutive years, or follow-up treatment with other methods, may be required to control medusahead. In some cases, 2 consecutive years of burning can nearly eliminate an infestation because medusahead soil seed banks are short lived [32, 35]. Fuel loads in these annual grasslands are typically sufficient to carry fires in several consecutive years [57]. Regular monitoring and plans for retreatment are important, especially during the first few years until the seedbank is depleted [32].

Fire is less likely to be effective at controlling medusahead in perennial grasslands and shrublands, such as shrub-steppe ecosystems in the Intermountain West, where fuels are less continuous and native plants are not adapted to frequent fire [35, 45, 57]. When perennials are dry enough to carry fire, medusahead seeds have already dispersed and are less susceptible to fire damage. Thus, prescribed fires in perennial grasslands are less selective, have greater impact on associated species, and have less impact on medusahead than fires in annual rangelands [45]. In sagebrush steppe, persistence and/or establishment of perennial bunchgrasses is important for limiting reestablishment of medusahead after treatments to remove it. In a synthesis of control methods for medusahead in sagebrush-steppe, Johnson and Davies [41] recommended a three-step process to control medusahead and promote perennial grasses in areas where medusahead had developed a thick layer of thatch: prescribed burning followed by pre-emergent herbicide (imazapic) application in fall, followed by seeding desirable species 1 year later. A delay in seeding was recommended because of potential negative effects of herbicides on seeded species [41]. However, this method may only provide short-term (1-2 years) medusahead control. In a systematic review and meta-analysis of control effects on medusahead, combinations of fire, herbicide, and seeding resulted in the greatest reductions of medusahead in perennial grasslands and shrublands, but effects did not persist beyond 1 year after treatment, on average [40].

Table 1. Publications on medusahead's response to fire

Study location	Plant community	Treatments investigated and time-since-treatment (time-since-fire)*	Main findings related to medusahead	Reference
Sagebrush-steppe in the Intermountain West				
CA: Lassen County	Wyoming big sagebrush with medusahead and/or cheatgrass	Prescribed fire (February), followed by preemergent (rimsulfuron, imazapic, or sulfometuron + chlorsulfuron), or postemergent (glyphosate) herbicide application (at multiple rates in October or April), and seeding mixes of native or nonnative perennial grasses and Wyoming big sagebrush (at multiple rates in September, 1 year after herbicide application) 1-3 years (2-4 years)	• In posttreatment year 1, burned and seeded plots treated with preemergent herbicides had the lowest mean medusahead cover (0%-0.7%) and seedhead density (0-8.0 seedheads/m^2) compared to burned and seeded plots treated with postemergent herbicide (cover: 4.4%; density: 114 seedheads/m^2) and burned control plots (cover: 11.3%; density: 221 seedheads/m^2). • In posttreatment year 2, only burned and seeded plots treated with imazapic had lower mean cover of medusahead (5.9%) than burned control plots (18.4%). • In posttreatment year 3, all treated plots had medusahead cover that was similar to or higher than burned control plots. • Seeding did not result in significant establishment or in changes in cover of seeded species, regardless of seed mix, planting method, or study site.	[48]**
CA: 2 cold-winter sites in Siskiyou and Modoc counties; see below for data from 2 warm-winter sites (blue oak woodland) examined in this study	Sagebrush steppe dominated by medusahead	Prescribed fire in 2 consecutive summers (May, June, or July) 1-2 years	• Prefire cover of medusahead averaged 70.8% and 58.0% in spring at the Siskiyou and Modoc county sites, respectively. • 1 year after the 1st fire, mean medusahead cover was 13.3% and 23.0% in spring, compared to 58.1% and 61.7% on unburned controls; it was 21.7% in summer, compared to 73.5% on unburned controls at the Siskiyou county site (no summer data were collected at other sites) • 1 year after the 2nd fire, mean medusahead cover was 6.3% and 76.5% in spring, compared to 85.9% and 49.5% cover on unburned controls. • 2 years after the 2nd fire, mean medusahead cover was 20.3% and 79.5% in spring, compared to 44.7% and 77.8% cover on unburned controls.	[46]**

CA and OR: Lassen, Yolo, and Yuba counties, CA and Lake County, OR	Low sagebrush community dominated by medusahead	Disturbance treatments (October, November or April), followed by, imazapic application (at multiple rates up to 7 days after disturbance treatments), and/or seeding mixes of native and nonnative perennial grasses (soon after imazapic application and again in spring and/or fall 6 months to >1 year after application) Disturbance treatments included burning with a propane torch (in Lassen and Lake counties), tilling (in Lake, Lassen, and Yuba counties), and/or mowing and raking (in Yolo County). 2-19 months (7-19 months)	• At Lassen County, mean medusahead cover was not different on burned-only and unburned plots 19 months after fire, but cover in burned-only plots (~43%) was greater than that in burned-and-imazapic-treated plots (~8%-12%). • At Lake County, mean medusahead cover in burned or tilled plots where imazapic was applied in spring (spring-treated plots) was similar to cover in burned or tilled plots where imazapic was applied in fall (fall-treated plots) the June following treatments (2 and 7 months after treatments, respectively). However, the following June, mean medusahead cover was lower in spring-treated plots than fall-treated plots. • Overall, imazapic application was more effective at reducing medusahead cover when applied to disturbed than undisturbed plots.	[43]**
ID: near Boise	Medusahead grasslands in former Wyoming big sagebrush-bluebunch wheatgrass steppe	Prescribed fire (October), followed by raking or rototilling (October), followed by imazapic application (at 4 rates in October or March), followed by seeding mixes of native and nonnative perennial grasses, perennial forbs, and shrubs (at 5 rates in October) Various treatment combinations were applied at various times over 4 years. 7 months	• Medusahead cover was lower in burned (~4%) than unburned (~7%) plots 7 months after treatments. • Nonnative annual grass abundance (mostly medusahead) was lowest after a combination of prescribed fire followed by rototilling, imazapic application, and seeding at high rates. This combination also yielded high densities of seeded species during treatment years with wet growing seasons that followed winters with few freeze-thaw intervals.	[66]

OR: between Crane and Juntura	Medusahead grasslands in former Wyoming big sagebrush-bunchgrass steppe	Prescribed fire (September), imazapic application (10 days after fire), and seeding crested wheatgrass and Siberian wheatgrass (October, >1 year after other treatments) 1-5 years (2-6 years)	• In posttreatment year 1, plots treated with a combination of fire, imazapic, and seeding had lower cover (<1%) and density (less than ~100 plants/m^2) of nonnative annual grasses (mostly medusahead) than untreated plots (cover: ~15%; density: ~1,200 plants/m^2). • In posttreatment year 5, nonnative annual grass cover (~11%) and density (1,200 plants/m^2) in treated plots remained lower than that in untreated plots (cover: ~24%; density: ~2,500 plants/m^2). • Treated plots had higher large perennial bunchgrass cover and density and lower annual forb cover and density (mostly nonnative annuals) than untreated plots for the duration of the study.	[16]**
OR: between Crane and Juntura	Medusahead grasslands in former Wyoming big sagebrush-bunchgrass steppe	Prescribed fire (September), followed by imazapic application (2 weeks after fire), and seeding either a mix of native species (squirreltail, bluebunch wheatgrass and Wyoming big sagebrush) or a mix of nonnative species (crested wheatgrass, Siberian wheatgrass and forage kochia) (October and December) Seeding occurred >1 year after other treatments. 1-3 years (2-4 years)	• Nonnative annual grass cover and density (mostly medusahead) in native-seeded plots were 2 to 6 times greater than that in nonnative-seeded plots during posttreatment years 1 to 3. • Nonnative annual grass cover and density increased with time since seeding in both native-seeded and nonnative-seeded treatments. • 3 years after treatments, perennial bunchgrass cover and density were 5 to 10 times greater in nonnative-seeded plots than native-seeded plots.	[17]

OR: between Crane and Juntura	Medusahead grasslands in former Wyoming big sagebrush-bunchgrass steppe	Single entry (all treatments during same year in fall): Prescribed fire, followed by imazapic application, and seeding crested wheatgrass and Siberian wheatgrass Multiple entry: Prescribed fire, followed by imazapic application (fall), and seeding (fall, 1 year after other treatments) 1-2 years (1-3 years)	• In posttreatment year 2, annual grass cover and density (mostly medusahead) were lower in single-entry plots (cover: <1%; density: <10 plants/m^2) and multiple-entry plots (cover: ~3%; density: ~60 plants/m^2) than in untreated plots (cover: ~8%; density: ~500 plants/m^2) • In posttreatment year 2, perennial grass cover was 8 times greater in multiple-entry plots than single-entry plots.	[21]
OR: Crooked River National Grasslands	Medusahead- and cheatgrass-invaded sagebrush steppe with western juniper expansion	Prescribed fire alone (July), and prescribed fire (July) followed by seeding with either a mix of native species (perennial grasses and Lewis flax) or a mix of native and nonnative species (perennial grasses and Lewis flax) (December, same year as fire) 2-6 years	• In posttreatment year 2, medusahead cover was lower in treated (burned, burned-native seeded, and burned-native and nonnative seeded) plots (less than ~10%) than untreated plots (~30%). • In posttreatment year 4, medusahead cover in treated and untreated plots was similar. • In posttreatment year 6, medusahead cover in treated plots (~40%) was greater than that in untreated plots (~18%). • Large bunchgrass cover was 1.9 to 2.3 times greater on untreated than treated plots in posttreatment year 6.	[18]

OR: Crook, Jefferson, Wasco, and Wheeler counties	Western juniper-basin big sagebrush/ cheatgrass communities along a precipitation gradient	2 treatments to remove western juniper: prescribed fire (September and October) or harvest (October) Bags of medusahead seeds were buried or placed on the soil surface in untreated plots to determined seed bank longevity. Seeds were placed in June and collected 6 to 24 months after placement. Medusahead seeds were planted under tree canopies and in interspaces in burned, harvested, and untreated plots (following treatments and 1 year after treatments) to test for invasion potential.	• Most (80%) medusahead seeds in seed bags germinated within 2 years. Dormancy of seeds occurred in both buried (12%) and surface (14%) seed bags, regardless of duration in the field. • Medusahead emergence (60%-75%) and survival (85%-95%) were high, regardless of site or treatment type. • Medusahead seed production was at least 80% greater in burned plots than either untreated or harvested plots. • Medusahead seed production was at least 32% higher under tree canopies than in interspaces. • A population growth model suggested that burned plots had a higher risk of medusahead invasion than untreated plots, regardless of site and year. Medusahead population growth rates estimated for burned plots were greater than those for untreated or harvested plots, and were greater under tree canopies than in tree interspaces.	[84]
OR: near Burns	Medusahead grasslands in former Wyoming big sagebrush and low sagebrush steppe	Prescribed fire (May or October) and/or imazapic application (October) 1-2 years (1-3 years)	• In posttreatment years 1 and 2, plots treated with a combination of spring or fall burning followed by imazapic application had the lowest density (less than ~5 plants/m^2) and the lowest cover (less than ~1%) of medusahead among 5 treatment combinations and the untreated control. • In posttreatment year 2, plots treated with a combination of spring or fall burning followed by imazapic application had the highest density and cover of large perennial bunchgrasses.	[19]**
OR: near Burns	Medusahead grasslands in former Wyoming big sagebrush and low sagebrush steppe	Prescribed fire (May or October) and/or imazapic application (October) All treated plots were seeded with desert wheatgrass and squirreltail (September, 1 year after herbicide application). 1-2 years (1-3 years)	• In posttreatment years 1 and 2, nonnative annual grass cover and density (mostly medusahead) were lowest, and large perennial bunchgrass cover and density were highest in spring and fall burned-imazapic-seeded plots when compared among 6 treatment combinations and the untreated control. • In posttreatment years 1 and 2, plant species diversity was highest in spring and fall burned-imazapic-seeded plots and in spring burned-seeded plots.	[22]

OR: near Burns	Medusahead grasslands in former Wyoming big sagebrush or low sagebrush steppe	Wildfire (July) followed by seeding native and nonnative perennial grasses and Lewis flax (at multiple rates in October) 7-32 months (10-34 months)	• Cover and density of nonnative annual grasses (mostly medusahead) were lower on seeded (~200 plants/m^2) than unseeded (~400 plants/m^2) plots 3 years after fire. • Establishment of native (~4 plants/m^2) and nonnative (~2 plants/m^2) perennial grasses was lower than desired on seeded plots 3 years after fire.	[25]**
OR: near Drewsey	Medusahead grasslands in former Wyoming big sagebrush steppe	Prescribed fire (October) followed by imazapic application (October) on all plots, including the control Treated plots were seeded with various mixes of native and nonnative perennial grass and forbs (October, 1 year after fire and herbicide application). 1-3 years (2-4 years)	• Despite relatively high establishment of large perennial grasses (~8 plants/m^2) following seeding, nonnative annual grass cover and density (likely, mostly medusahead) did not differ between seeded and unseeded plots in posttreatment years 1 to 3. • Total perennial herbaceous and nonnative annual grass abundance were similar in plots seeded with only large perennial bunchgrasses and those seeded with a diversity of species.	[24]
OR: near Drewsey and near John Day	Medusahead-infested pastures	Prescribed fire (June), followed by imazapic application (at multiple rates in July, August, September, or October), followed by seeding with native or nonnative perennial grasses or shrubs (November) 1-2 years	• In posttreatment year 1, medusahead cover tended to be higher in unburned control plots than in burned plots, and among treated plots its cover tended to be highest in plots without imazapic application and lowest in plots with high imazapic application rates. By posttreatment year 2, these patterns were less evident. • The effects of herbicide application timing and rate on nontarget vegetation were not consistent among sites or posttreatment years.	[72]**

OR: near Fossil and near Spray	Medusahead grasslands in former bluebunch wheatgrass/ Idaho fescue communities	Prescribed fire (October) and/or imazapic application (October) followed by seeding a mix of native and nonnative perennial grasses and alfalfa (5 days after fire) 1-4 years	• Burned-imazapic plots had lower medusahead density than burned-only plots in posttreatment year 1 (~20 plants/m^2 vs. ~420 plants/m^2) and posttreatment year 2 (~420 plants/m^2 vs. ~900 plants/m^2). However, medusahead density was similar between burned-imazapic and burned-only plots in posttreatment years 3 and 4. • In posttreatment year 1, plots treated with imazapic-only had lower medusahead density (~100 plants/m^2) than untreated plots (~800 plants/m^2), but density was similar between imazapic-only plots and untreated plots in posttreatment years 2 to 4. • Among all treatment combinations, burned-imazapic plots had the lowest medusahead density in posttreatment years 1 and 2, but all plots were similar in posttreatments years 3 and 4.	[71]**
UT: near Avon	Grasslands dominated by medusahead, cheatgrass, bulbous bluegrass, annual ragweed, and curlycup gumweed	Prescribed fire (October), followed by imazapic, sulfometuron, or glyphosate + metsulfuron methyl (at multiple rates in October or April), followed by seeding various combinations of native and nonnative perennial grasses, forbs, and shrubs (at multiple rates in November or March, during the fire year and 1 year after fire) Treatments occurred at 2 sites. The fire burned 5% to 10% of the West Site (a site with low litter cover) and 70% to 80% of the East Site (a site with high litter cover). 2-20 months (8-20 months)	• In posttreatment year 1, medusahead abundance was most reduced (relative to control plots) on plots receiving the high rate of fall-applied sulfometuron compared to plots receiving other herbicide treatments at both sites. • In posttreatment year 2, medusahead abundance was most reduced on plots receiving the high rate of spring-applied imazapic at the East Site, and on plots receiving fall-applied sulfometuron at the West Site. • No seeded perennial species established in either year at either site.	[58], some data also in [54]**

Grasslands and oak woodlands in foothills and valleys of California and western Oregon				
CA: Butte County	Purple needlegrass community with abundant medusahead	Prescribed fire (October) 7 months	• Medusahead cover was reduced by 17% after fire compared to prefire cover. • Density of medusahead seeds in the soil seed bank was reduced by 40% after fire compared to prefire density, but the difference was not significant.	[38]
CA: Gallatin Ranch, Tehama County	Medusahead-dominated annual grasslands	Prescribed fire (June) 1-3 years	• Mean medusahead cover was reduced from 77% before fire to 4% in postfire year 1, when mean cover in unburned plots was 69%. • After postfire year 1, medusahead cover increased in burned plots and decreased in unburned plots so that in postfire year 3, cover of medusahead was higher in burned (18%) than unburned (14%) plots. • While not dominant before fire, Stork's bill was dominant during postfire years 1 to 3. Its cover increased from 4% before fire to 55% in postfire year 3. Stork's bill cover also increased on unburned plots from 11% before fire to 55% in postfire year 3.	[29]
CA: Mitsui Ranch, Sonoma County	Annual grasslands with medusahead	Cattle grazing for 4 months during the 2 years prior to treatment and for 2 months during the year of treatment, followed by prescribed fire (June), followed by seeding a mix of native perennial and annual grasses (at various rates in January), followed by short-duration cattle grazing at a high stocking rate (March) Untreated control plots were also grazed. 5 months (1 year)	• Before treatments, mean medusahead cover was 13%. • Mean medusahead cover increased by 15% in control plots but decreased by 8% in treated plots 5 months after treatments. • Medusahead seed density in the soil seed bank was lower after treatments (<7 individuals germinated from seed bank samples) than before treatments (19 individuals germinated). • Overall, species richness and diversity was higher in treated than untreated plots.	[4]

CA: Sierra Foothill Research and Extension Center	Annual grasslands with medusahead- and/or barbed goatgrass within oak savannas and former oak savannas	1, 2, or 3 consecutive-year prescribed fires (June and/or July, after other grasses senesced) 1-2 years	• Mean medusahead cover before burning ranged from 24% to 71% on the 3 study sites. • After a single fire, mean medusahead cover ranged from 0% to 4% in postfire year 1. It ranged from 4% to 6% in postfire year 2, compared to 19% to 60% cover in unburned plots. • After 2 consecutive fires, medusahead cover was 0% to 2% in burned plots compared to 19% to 60% in unburned plots. • Medusahead plants on once- or twice-burned plots produced more seeds/inflorescence (25 seeds/inflorescence), but fewer total inflorescences (0.3 inflorescence/100 cm^2), and fewer total seeds (6 seeds/100 cm^2) than plants on unburned plots (14 seeds/inflorescence, 9.4 inflorescence/100 cm^2, and 127 seeds/100 cm^2, respectively). • Mean patch size of medusahead infestations was smaller 1 year after a single fire than before fire.	[7]**
CA: Sierra Foothill Research and Extension Center	Annual grasslands with medusahead	Prescribed fire (May) and/or "seed-dispersal limitation" (current year's growth cut with a weed-whipper on all sides of plots) Immediately after treatments were completed, seed traps were placed and surface seeds collected to determine medusahead seed rain and germination rates, respectively. 4 months to 1 year	• Mean medusahead seed rain on burned plots (~34 seeds/plot) was higher than that on seed-limited plots (~7 seeds/plot) and untreated control plots (~10 seeds/plot) and similar to seed-limited-and-burned plots (~12 seeds/plot). • Medusahead germination rates were lower on burned (0.1%) than untreated (88%) plots. • Medusahead stem densities in burned (~2 stems/400 cm^2) and seed-limited-and-burned plots (<1 stem/400 cm^2) were lower than in seed-limited plots (~41 stems/400 cm^2) but statistically similar to untreated plots (~22 stems/400 cm^2).	[3], also in [5]

CA: 2 warm-winter sites in Fresno and Yolo counties; see above for data from 2 cold-winter sites (sagebrush steppe) examined in this study	Blue oak woodlands	Prescribed fire in 2 consecutive summers (May, June, or July) 1-2 years	• Prefire cover of medusahead averaged 27% and 29% in spring, and 39% and 63% in summer at the Fresno and Yolo county sites, respectively. • 1 year after the 1st fire, mean medusahead cover was 0% and 0.3% in spring, compared to 15% and 40% on unburned controls; and mean medusahead cover was 0.7% and 11% in summer, compared to 38% and 73% on unburned controls. • 1 year after the 2nd fire, mean medusahead cover was 0% and 0.7% in spring, compared to 36% and 56% on unburned controls; and mean medusahead cover was 0.3% and 3% in summer, compared to 48% and 65% on unburned controls. • 2 years after the 2nd fire, mean medusahead cover was 0.2% and 9% in summer, compared to 30% and 77% cover on unburned controls.	[46]**
CA: Yuba County	Yellow-starthistle community with medusahead and ripgut brome	1 prescribed fire (June or July) followed by either a clopyralid application (March or April) or a 2nd prescribed fire in the consecutive year; or 1 clopyralid application followed by either a 2nd clopyralid application or a prescribed fire in the consecutive year 1 year (1-2 years)	• Among 4 treatment combinations and the control, medusahead cover in posttreatment year 1 was lowest in plots treated with prescribed fires in 2 consecutive years (<1%) and in plots treated with a 1st-year clopyralid application followed by a 2nd-year prescribed fire (<1%). It was highest in plots treated with clopyralid in 2 consecutive years and in untreated control plots.	[34]**

OR: Carson Prairie at Oregon State University's Dunn Research Forest	Nonnative annual grassland dominated by medusahead, bristly dogstail grass, soft brome, and wild oat, and a native bunchgrass grassland dominated by Roemer's fescue and blue wildrye	Clipping and raking to add or remove litter, followed by prescribed fire (September), followed by seeding various combinations of native and nonnative perennial, biennial, and annual grasses and forbs (soon after fire) 8 months	• On the nonnative annual grassland site, burned plots had more seedlings of seeded native species (17-36) than untreated plots (3-11), but the number of medusahead seedlings was not significantly different between burned and seeded (25) and untreated (9) plots. • On the native bunchgrass site, burned plots had a similar number of seeded native seedlings (17-23) as untreated plots (10-31), but the number of medusahead seedlings was higher on burned and seeded (50) than untreated (14) plots.	[51]
Common garden/laboratory				
CA: University of California, Davis, Plant Sciences Field Station, Yolo County	Seedheads collected (May-July) from medusahead monocultures grown in a common garden	Experimental exposure of seedheads to direct flame and convective heat within 24 hours of collection Germination tests were conducted 7-8 months after exposure.	• Overall, medusahead seed maturity or moisture levels did not affect susceptibility to mortality from convective heat or flame exposure. • Medusahead seed mortality increased with increasing exposure time and temperature.	[85]

*If different than time-since-treatment.

**Publication included in the systematic review and meta-analysis of control effects on medusahead published by James et al. [40].

Other Management Considerations

Tools and strategies for managing medusahead differ among regions and plant communities where medusahead is invasive, but in all cases long-term control requires an integrated approach that includes reducing medusahead abundance, limiting reestablishment, promoting desirable species, and preventing new infestations. Reducing medusahead abundance may be best achieved by optimizing the timing of control treatments to coincide with vulnerable phenological stages [1, 32, 57]. Combining treatments can increase the effectiveness and duration of control [57]. For example, using prescribed fire, mechanical methods, or livestock grazing to remove the medusahead thatch layer prior to herbicide application reduces the amount of herbicide needed, decreases reestablishment of medusahead from the soil seed bank, and increases establishment sites for desirable vegetation in the short term [1, 35, 57]. Native grassland vegetation may benefit from increased light penetration, soil temperature, and nutrient availability resulting from thatch removal [32, 45]. Seeding desirable vegetation after reducing medusahead abundance may be necessary to achieve long-term medusahead control [35, 41, 57]. Nafus and Davies [57] suggest focusing on areas with remnant native vegetation when treating large infestations to improve revegetation success. In addition, Johnson and Davies [41] noted that "the smaller the infestation and the earlier it is detected, the greater the chance for successful eradication". Table 2 provides information from studies on medusahead's response to control treatments other than fire that were published between 2000 and 2019. The following is a general summary of nonfire control methods based primarily on information from three syntheses [35, 41, 57] and one systematic review and meta-analysis [40], with information from additional publications as needed.

Prevention

The most effective management strategy for medusahead is to prevent its establishment and spread by maintaining ecologically functional plant communities, limiting medusahead seed dispersal, and establishing a program for monitoring and early detection [45]. For example, suggestions for maintaining perennial bunchgrass density include periodic growing-season rest from livestock grazing, using livestock to reduce fuel loads to reduce wildfire severity and damage to perennial bunchgrasses, minimizing disturbance, and seeding desirable species after wildfires [41].

Short-distance seed dispersal may be limited by controlling plants along borders of existing populations and/or by maintaining neighboring vegetation taller than medusahead that can physically intercept medusahead seeds. Long-distance seed dispersal may be limited by restricting vehicle, human, and livestock travel from infested to uninfested areas, especially when seeds are mature [41, 45, 57].

Detecting new populations when they are small improves chances for eradication and preventing persistence and spread on new sites. This may be achieved with regular monitoring of susceptible areas, such as areas near established populations and along roads and trails [41, 45, 57].

Control Methods

In addition to fire (see Fire Management Considerations), control methods include herbicides, manual and mechanical controls, livestock grazing, biological controls, and combinations of these [41, 57]. Combining control methods may be more effective than any method alone, but follow-up monitoring and control are necessary. A 2015 systematic review and meta-analysis on medusahead response to control treatments found a lack of information on medusahead response beyond 3 years after treatment: of the 22 studies included, 22% monitored medusahead response for only 1 year, 63% monitored it for 2 or 3 years, and only 3 studies monitored medusahead response for more than 3 years [40].

Chemical control

Many herbicides have been tested for controlling medusahead, and their application and efficacy depend on a number of factors including site characteristics, the present and desired plant community, revegetation plans, and local regulations [57]. See DiTomaso et al. [35], Kyser et al. [45], and Nafus and Davies [57] for information on efficacy and use of specific chemicals.

A systematic review and meta-analysis on the effects of herbicides on medusahead abundance showed that combining herbicides with other control methods resulted in better short-term control of medusahead than herbicides alone in both annual grasslands and perennial grasslands and shrublands. In annual grasslands, combining herbicides with seeding reduced medusahead abundance more than herbicides alone in posttreatment years 1 to 4. In perennial grasslands and shrublands, the combination of herbicides and seeding with and without prescribed fire reduced medusahead abundance more than herbicides alone in posttreatment year 1, but not in posttreatments years 2 to 4 [40].

Manual and mechanical control

Mechanical control of medusahead can be destructive to soils and remnant desirable plants and is rarely feasible in shrub-steppe communities. In annual grasslands, mechanical treatments (raking, mowing, plowing, disk harrowing, furrowing, or tilling) may reduce medusahead cover for 1 posttreatment year. Raking to remove medusahead thatch may favor establishment of desirable plant species and improve the efficacy of subsequent applications of some soil-applied herbicides, such as imazapic. Late-season mowing (in the early flowering stage before medusahead sets seed) may help to suppress medusahead, whereas early-season mowing is likely to be ineffective and may harm desirable species. Mowing after seed set is not recommended because it will disperse seeds [35, 45]. Tilling is rarely a management option for medusahead in wildlands, but can decrease medusahead abundance in the short term by killing plants, burying seeds, and breaking up thatch layers. Tilling prior to herbicide application can improve its efficacy and prepare seedbeds for desirable species. Tilling after seed set is not recommended [1, 35, 45].

Livestock grazing

Medusahead is palatable to cattle and domestic sheep early in the season before seedheads emerge, but not when plants are mature [35, 57], although at high stocking rates domestic sheep graze medusahead in all stages of maturity [45]. Early season is also the time when medusahead cover and seed production are most likely to be reduced by grazing [35, 45]. A systematic review and meta-analysis on the effects of livestock grazing on medusahead abundance in annual grasslands found that cattle and domestic sheep grazing reduced medusahead abundance in posttreatment year 1, but not in posttreatments years 2 to 4 [40]. Intense livestock grazing on associated desirable species or inappropriately timed grazing may increase medusahead abundance [41, 45, 57]. To limit seed dispersal, livestock should be removed before plants mature [35, 57]. See Kyser et al. [45] for more information on the effects of cattle and domestic sheep grazing on medusahead.

Biological control

As of this writing (2019), no biological control agents have been approved for managing medusahead. The following publications provide information on potential biocontrol agents for medusahead, many of which are fungi that cause crown and root rot or infect the leaves of medusahead: [2, 6, 30, 35, 42, 45, 76]. See table 2 for more information.

Revegetation

Seeding desirable vegetation after removing medusahead thatch may help limit medusahead reestablishment and spread [45]. For example, in shrub-steppe ecosystems, abundance of native perennial bunchgrasses has a strong influence on establishment and spread of medusahead. However, establishing desirable vegetation by seeding is often unsuccessful, and varied success may be due to differences in site characteristics (topography, elevation, and climate), fire characteristics (timing and intensity), weather, and revegetation methods (native vs. nonnative materials and seeding and planting techniques) [45]. See Kyser et al. [45] and Nafus and Davies [57] for more information on revegetation considerations, techniques, and materials.

Table 2. Publications on medusahead's response to nonfire control treatments.

Study location	Plant community	Title	Treatments investigated	Reference
Sagebrush-steppe in the Intermountain West				
CA: Fly-Blown Flat in northeast	Low sagebrush "susceptible to medusahead invasion"	30 years of medusahead: return to Fly Blown-Flat	Grazing by cattle and herbicide application (2,4-D and/or atrazine)	[89]
CA: Modoc County	Big sagebrush scrub	Selective control of medusahead (Taeniatherum caput-medusae) in California sagebrush scrub using low rates of glyphosate	Herbicide application (glyphosate)	[44]*
ID: near Boise	Wyoming big sagebrush steppe with medusahead and cheatgrass	Controlling annual grasses with OUST® herbicide	Herbicide application (sulfometuron methyl)	[69]
ID: near Genesee	Nonnative annual grasslands	The response of yellow starthistle (Centaurea solstitialis), annual grasses, and smooth brome (Bromus inermis) to imazapic and picloram	Herbicide application (imazapic or picloram)	[75]
OR: central	Bunchgrass rangelands dominated by medusahead or cheatgrass	Control of medusahead and cheatgrass in central Oregon rangelands using Olympus®, 2006	Herbicide application (imazapic, glyphosate, and/or propoxycarbazone)	[10]
OR: central	Bunchgrass rangelands dominated by medusahead or cheatgrass	Control of medusahead and cheatgrass on central Oregon rangelands using Outrider® and Roundup® Pro alone and in combination, 2006	Herbicide application (glyphosate, imazapic and/or sulfosulfuron)	[9]
OR: central	Bunchgrass rangelands dominated by medusahead or cheatgrass	Control of medusahead and cheatgrass on central Oregon rangelands using Outrider® and Roundup® Pro alone and in combination, 2006-2007	Herbicide application (glyphosate, imazapic and/or sulfosulfuron)	[12]

OR: central Oregon	Bunchgrass rangelands dominated by medusahead or cheatgrass	Control of medusahead and cheatgrass on central Oregon rangelands with Landmark, Matrix, Plateau and Journey, 2006-2007	Herbicide application (imazapic, imazapic + glyphosate, rimsulfuron, or sulfosulfuron + chlorsulfuron)	[11]
OR: Harney County	Native perennial grasslands and sagebrush/perennial grasslands	Native forb response to sulfometuron methyl on medusahead-invaded rangeland in eastern Oregon	Herbicide application (sulfometuron methyl)	[49]
OR: Malheur County	Wyoming big sagebrush and big sagebrush steppe with understories dominated by medusahead and/or cheatgrass	Landscape-scale rehabilitation of medusahead (Taeniatherum caput-medusae)-dominated sagebrush steppe	Herbicide application (imazapic) and seeding crested wheatgrass and Sandberg bluegrass	[74]*
OR: near Burns	Former Wyoming big sagebrush steppe dominated by nonnative annual grasses, including medusahead and cheatgrass Both sites had burned in wildfires 15 years prior to the study.	Established perennial vegetation provides high resistance to reinvasion by exotic annual grasses	Herbicide application (glyphosate and imazapic) and planting various combinations of native and nonnative perennial grasses and shrubs	[23]
OR: near Burns	Medusahead grasslands and cheatgrass grasslands in former Wyoming big sagebrush steppe	Incorporating seeds in activated carbon pellets limits herbicide effects to seeded bunchgrasses when controlling exotic annuals	Herbicide application (glyphosate and imazapic), activated carbon pellets, and seeding native or nonnative perennial grasses or shrubs	[15]
OR: near Burns	Medusahead grasslands and cheatgrass grasslands in former Wyoming big sagebrush steppe	Using activated carbon to limit herbicide effects to seeded bunchgrass when revegetating annual grass-invaded rangelands	Herbicide application (imazapic), activated carbon pods, and seeding crested wheatgrass	[20]

OR: near Burns	Medusahead grasslands in former Wyoming big sagebrush and low sagebrush communities	Non-native competitive perennial grass impedes the spread of an invasive annual grass	Seeding desert wheatgrass	[26]
OR: near Drewsey and near Riverside	Wyoming big sagebrush/bluebunch wheatgrass community with an understory of bluebunch wheatgrass and medusahead	Response of bluebunch wheatgrass and medusahead to defoliation	Clipping and hand-pulling	[73]
OR: near Drewsey and near Venator	Wyoming big sagebrush/bluebunch wheatgrass community with an understory of crested wheatgrass	Crested wheatgrass defoliation intensity and season on medusahead invasion	Clipping crested wheatgrass and seeding medusahead**	[70]
OR: near Juntura in Malheur County	Medusahead grassland in former sagebrush steppe	Role of dispersal timing and frequency in annual grass-invaded Great Basin ecosystems: How modifying seeding strategies increases restoration success	Herbicide application (glyphosate), tilling, and seeding various combinations of native perennial grasses with medusahead and cheatgrass**	[65]
UT: Logan and Mantua	Mountain big sagebrush community with medusahead in the understory (~10% cover)	Effects of early experience and alternative feeds on medusahead (Taeniatherum caput-medusae spp. asperum) intake by sheep	Grazing by domestic sheep	[56]
UT: Mantua	Mountain big sagebrush community with an understory dominated by medusahead and cheatgrass	Effects of energy supplementation and time on use of medusahead by grazing ewes and their lambs	Grazing by domestic sheep	[55]

WA: Grant, Franklin, Adams, Klickitat, and Whitman counties	Sandberg bluegrass and squirreltail rangeland, winter wheat cropland, alfalfa or timothy pasture, and a laboratory	Selective soil bacteria to manage downy brome, jointed goatgrass, and medusahead and do no harm to other biota	Biocontrol (*Pseudomonas fluorescens*, a soil bacterium)	[42]
WA: near Ritzville	Nonnative annual grasslands formerly dominated by sagebrush steppe	Effect of protein supplementation on forage utilization by cattle in annual grass-dominated rangelands in the Channeled Scablands of eastern Washington	Grazing by cattle	[80], also in [82]
WA: near Ritzville	Nonnative annual grasslands formerly dominated by sagebrush steppe	Chapter 5: Seeding medusahead-invaded rangeland following mechanical disturbance on the Channeled Scablands of eastern Washington	Disking and harrowing and seeding Siberian wheatgrass and forage kochia	[81]
WA: near Ritzville	Nonnative annual grasslands formerly dominated by sagebrush steppe and Palouse prairie	Revegetation of medusahead-invaded rangelands in the Channeled Scablands of eastern Washington	Herbicide application (glyphosate, 2,4-D, chlorsulfuron, sulfometuron methyl, and picloram), plowing and harrowing, and seeding mixes of native and/or nonnative perennial grasses and forage kochia	[83], also in [82]
Annual grasslands and oak woodlands in foothills and valleys of California and western Oregon				
CA: Bear Creek Management Unit of the Cache Creek Natural Area, Colusa County	Annual grasslands and blue oak woodlands with understories dominated by medusahead and yellow starthistle	Introducing cattle grazing to a noxious weed-dominated rangeland shifts plant communities	Grazing by cattle	[28]

CA: Bobcat Ranch, Yolo County	Annual grasslands dominated by medusahead mixed with blue oak woodlands	Control of medusahead (Taeniatherum caput-medusae) using timely sheep grazing	Grazing by domestic sheep	[33]*
CA: Glen and Yolo counties	Medusahead-dominated annual grasslands	Targeted grazing impacts on invasive and native plant abundance change with grazing duration and stocking density	Grazing by cattle and domestic sheep	[39]
CA: Hopland Research and Extension Center and California Route 29 roadsides	Nonnative annual grasslands with medusahead	Natural product herbicides for control of annual vegetation along roadsides	Herbicide application (glyphosate, acetic acid, pine oil extract, or plant essential oils)	[92]
CA: Tehama County	Blue oak woodlands with an understory dominated by soft chess, bristly dogstail grass, and medusahead	Conservation easements in California blue oak woodlands: testing the assumption of livestock grazing as a compatible use	Grazing by cattle	[60]*
CA: Tehama, Yolo, and Yuba counties	Annual grasslands with medusahead within blue oak woodlands	Preemergent control of medusahead on California annual rangelands with aminopyralid	Herbicide application (aminopyralid, imazapic, or rimsulfuron)	[47]*
CA: throughout	Coastal scrub, chaparral, oak woodland, and coniferous forest vegetation types	Fuel breaks affect nonnative species abundance in Californian plant communities	Wildland fuel breaks created with hand tools and/or mechanical equipment	[52]
CA: central and north-central	Annual grasslands with medusahead	Timing aminopyralid to prevent seed production controls medusahead (Taeniatherum caput-medusae) and increases forage grasses	Herbicide application (aminopyralid)	[61]

CA: University of California Sierra Foothills Research and Extension Center	Annual grasslands dominated by medusahead (95% cover) and blue oak-interior live oak woodlands with an understory of medusahead (<1% cover)	Interactions among habitat, management, and demography for an invasive annual grass	Mowing and clipping, herbicide application (glyphosate), shading, litter application, and seeding nonnative annual and perennial grasses and forbs, including medusahead**	[37]
CA: University of California Sierra Foothills Research and Extension Center	Valley grasslands and coastal prairie with ~30%-40% cover of medusahead	Grassland compost amendments increase plant production without changing plant communities	Grazing by cattle and compost amendments	[64]
CA: University of California Sierra Foothill Research Extension Center	Valley grasslands dominated by native perennial bunchgrasses, nonnative annual forage grasses, or medusahead	Evaluating ecosystem services provided by non-native species: an experimental test in California grasslands	Trampling by cattle and mowing	[78]
CA: University of California Sierra Foothill Research Extension Center	Valley grasslands dominated by native perennial bunchgrasses, nonnative annual forage grasses, or medusahead	Transitions and invasion along a grazing gradient in experimental California grasslands	Trampling by cattle and mowing	[79]
CA: west side of Sacramento Valley	Patches of medusahead and barbed goatgrass within annual grasslands	Novel fine-scale aerial mapping approach quantifies grassland weed cover dynamics and response to management	Grazing by cattle, domestic sheep, and domestic goats	[50]

CA: Yolo County	Medusahead-dominated annual grasslands	Using phenology to optimize timing of mowing and grazing treatments for medusahead (Taeniatherum caput-medusae)	Clipping	[8]
CA: Yolo County	Modeled medusahead grasslands	A model to optimize grazing management for control of medusahead (Elymus caput-medusae) in California rangelands	Grazing by cattle	[91]
CA: Yolo County	Pastures dominated by medusahead	Chaper 2: Control of medusahead [Taeniatherum caput-medusae (L.) Nevski] with precision grazing and reseeding	Grazing by domestic sheep and/or disking and seeding with a mix of native and nonnative annual and perennial grasses and annual legumes	[13]*
Common garden/greenhouse/laboratory/other				
CA: seeds collected from Yuba County	Greenhouse	Pre-emergence control of six invasive winter annual grasses with imazapic and indaziflam	Herbicide application (imazapic and/or indaziflam)	[67]
ID: seeds collected north of Bliss	Laboratory	Lack of host specialization on winter annual grasses in the fungal seed bank pathogen Pyrenophora semeniperda	Biocontrol (*Pyrenophora semeniperda*, a fungal pathogen)	[2]
NV: soils collected from field sites in semi-arid shrublands in Washoe County	Greenhouse	Competition, legacy, and priority and the success of three invasive species	Seeding a mix of native perennial grasses, common yarrow, and rubber rabbitbrush with medusahead, cheatgrass, or crested wheatgrass**	[59]

NV: soils and some seeds collected from Wyoming big sagebrush communities in northern Nevada	Common garden	Emergence and early survival of early versus late seral species in Great Basin restoration in two different soil types	Seeding a native early-seral seed mix of perennial grasses and forbs and Wyoming big sagebrush and a native late-seral seed mix of perennial grasses, annual forbs, and rubber rabbitbrush with and without medusahead or cheatgrass**	[88]
NV: soils and some seeds collected from Wyoming big sagebrush communities in northern Nevada	Common garden	First-year establishment, biomass and seed production of early vs. late seral natives in two medusahead (Taeniatherum caput-medusae) invaded soils	Seeding a native early-seral seed mix of perennial grasses and forbs and Wyoming big sagebrush and a native late-seral seed mix of perennial grasses, annual forbs, and rubber rabbitbrush with and without medusahead**	[87]
OR: not provided	Wind tunnel	Influence of neighboring vegetation height on seed dispersal: implications for invasive plant management	Clipping	[27]
OR: seeds collected near Monument	Greenhouse and growth chamber	Aminopyralid constrains seed production of the invasive annual grasses medusahead and ventenata	Herbicide application (aminopyralid)	[62]*

OR: soils collected from the Northern Great Basin Experimental Range; medusahead seeds collected from Harney County	Grow room	Native seeds incorporated into activated carbon pods applied concurrently with indaziflam: a new strategy for restoring annual-invaded communities?	Herbicide application (indaziflam), activated carbon pods, and seeding medusahead, bluebunch wheatgrass, and/or Wyoming big sagebrush**	[14]
UT: not provided	Greenhouse	Sulfosulfuron effects on growth and photosynthesis of 15 range grasses	Herbicide application (sulfosulfuron)	[53]*
UT and WA: plants collected from Mantua, UT and Ritzville, WA	Not provided	Exploring the fermentation kinetics of medusahead treated with glyphosate at different particle lengths	Herbicide application (glyphosate)	[77]
Outside the US: fungi collected from Cyprus, Greece, and Turkey	Growth chamber	Exploration for plant pathogens against Taeniatherum caput-medusae (medusahead ryegrass)	Biocontrol (*Fusarium arthrosporioides*, *Tilletia* spp., *Ustilago* spp., all smut fungi, and *Puccinia* spp., a rust fungus)	[90]
Outside the US: fungus collected from Greece	Laboratory	First report of Fusarium arthrosporioides on medusahead (Taeniatherum caput-medusae) and preliminary tests for host-specificity	Biocontrol (*Fusarium arthrosporioides*, a smut fungus)	[76]

Outside the US: fungus collected from Turkey	Laboratory and greenhouse	Screening grasses for susceptibility to Ustilago phrygica, a potential biological control pathogen for medusahead	Biocontrol (*Ustilago phrygica*, a smut fungus)	[6]
Outside the US: fungus collected from Turkey	Laboratory, greenhouse, and common garden	First evaluation of Ustilago phrygica for the biological control of Taeniatherum caput-medusae (Triticeae)	Biocontrol (*Ustilago phrygica*, a smut fungus)	[68]
Outside the US: mites collected from Italy, Serbia, Bulgaria, Turkey, and Iran	Laboratory	A new Aculodes species (Prostigmata: Eriophyoidea: Eriophyidae) associated with medusahead, Taeniatherum caput-medusae (L.) Nevski (Poaceae)	Biocontrol (*Aculodes altamurgiensis*, a plant mite)	[30]

*Publication included in the systematic review and meta-analysis of control effects on medusahead published by James et al. 2015 [40].

**These studies tested treatment effectiveness by seeding medusahead and/or other nonnative annual grasses and monitoring their posttreatment abundance, growth, and/or reproduction.

References

*Denotes publications with information on medusahead's response to fire or management with fire

**Denotes publications of particular importance with information on medusahead's response to fire (i.e., a literature review, synthesis, or meta-analysis). Highlights from these publications follow the reference in bold font.

**1. Archer, Amy J. 2001. Taeniatherum caput-medusae. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.usda.gov/database/feis/plants/graminoid/taecap/all.html. [93785].

This review summarizes information published before 2001 on medusahead's relationship with fire as well as its life history, regeneration strategies, general ecology, and management considerations.

2. Beckstead, J.; Meyer, S. E.; Ishizuka, T. S.; McEvoy, K. M.; Colemand, C. E. 2016. Lack of host specialization on winter annual grasses in the fungal seed bank pathogen Pyrenophora semeniperda. PLoS ONE. 11(3): 1-20. [93676].

*3. Berleman, Sasha A.; Suding, Katharine N.; Fry, Danny L.; Bartolome, James W.; Stephens, Scott L. 2016. Prescribed fire effects on population dynamics of an annual grassland. Rangeland Ecology & Management. 69(6): 423-429. [91625].

*4. Berleman, Sasha Alexandra. 2016. Chapter 2: Using prescribed fire to restore a medusahead invaded northern California Coast Range grassland. In: The role of fire in California's landscapes across spatial and temporal scales. Berkeley, CA: University of California, Berkeley. Dissertation: 13-30. [93836].

*5. Berleman, Sasha Alexandra. 2016. The role of fire in California's landscapes across spatial and temporal scales. Berkeley, CA: University of California, Berkeley. 62 p. Dissertation. [92450].

6. Bernet, D.; Dubin, J.; Smallwood, E. 2005. Screening grasses for susceptibility to Ustilago phrygia, a potential biological control pathogen for medusahead. Phytopathology. 95: S8-S9. [93677].

*7. Betts, Aimee Denise Kisayo. 2003. Chapter 2: A comparison of the ecology of goatgrass and medusahead in California grasslands. In: Ecology and control of goatgrass (Aegilops triuncialis) and medusahead (Taeniatherum caput-medusae) in California annual grasslands. Berkeley, CA: University of California, Berkeley. Dissertation: 26-101. [93834].

8. Brownsey, Philip; James, Jeremy J.; Barry, Sheila J.; Becchetti, Theresa A.; Davy, Josh S.; Doran, Morgan P.; Forero, Larry C.; Harper, John M.; Larsen, Royce E.; Larson-Praplan, Stephanie R.; Zhang, Jimin; Laca, Emilio A. 2017. Using phenology to optimize timing of mowing and grazing

treatments for medusahead (Taeniatherum caput-medusae). Rangeland Ecology and Management. 70: 210-218. [93678].

9. Butler, M.; Campbell, C.; Affeldt, R. 2007. Control of medusahead and cheatgrass on central Oregon rangelands using Outrider® and Roundup® Pro alone and in combination, 2006. Central Oregon Agricultural Research Center 2006 Annual Report. Special Report 1072. Agricultural Experiment Station Oregon State University. 18-20 p. [93841].

10. Butler, Marvin; Campbell, Claudia; Affeldt, Richard. 2007. Control of medusahead and cheatgrass in central Oregon rangelands using Olympus®, 2006. In: Central Oregon Agricultural Research Center 2006 Annual Report. Special Report 1072. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 21-23. [93847].

11. Butler, Marvin; Cominggore, Dan; Paye, Floyd. 2007. Control of medusahead and cheatgrass on central Oregon rangelands with Landmark, Matrix, Plateau and Journey, 2006-2007. In: Central Oregon Agricultural Research Center 2007 Annual Report. Special Report 1084. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 99-101. [93849].

12. Butler, Marvin; Crockett, Ron. 2007. Control of medusahead and cheatgrass on central Oregon rangelands using Outrider® and Roundup® Pro alone and in combination, 2006-2007. In: Central Oregon Agricultural Research Center 2007 Annual Report. Special Report 1084. Corvallis, OR: Oregon State University, Agricultural Experiment Station: 102-103. [93848].

13. Cherr, Corey Matthew. 2009. Chapter 2: Control of medusahead [Taeniatherum caput-medusae (L.) Nevski] with precision grazing and reseeding. In: Invasion, control, and distribution of medusahead [Taeniatherum caput-medusae (L.) Nevski] in California grasslands. Davis, CA: University of California Davis. Dissertation: 40-80. [93839].

14. Clenet, D. R.; Davies, K. W.; Johnson, D. D.; Kerby, J. D. 2019. Native seeds incorporated into activated carbon pods applied concurrently with indaziflam: A new strategy for restoring annual-invaded communities? Restoration Ecology. 27(4): 738-744. [93680].

15. Davies, K. W. 2018. Incorporating seeds in activated carbon pellets limits herbicide effects to seeded bunchgrasses when controlling exotic annuals. Rangeland Ecology and Management. 71(3): 323-326. [93683].

*16. Davies, K. W.; Boyd, C. S. 2018. Longer-term evaluation of revegetation of medusahead-invaded sagebrush steppe. Rangeland Ecology and Management. 71(3): 292-297. [92795].

*17. Davies, K. W.; Davies, C. S.; Boyd, D. D.; Nafus, A. M.; Madsen, M. D. 2015. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology and Management. 68(3): 224-230. [93365].

*18. Davies, K. W.; Dean, A. E. 2019. Prescribed summer fire and seeding applied to restore juniper-encroached and exotic annual grass-invaded sagebrush steppe. Rangeland Ecology and Management. 72(4): 635-639. [93518].

*19. Davies, K. W.; Johnson, D. D. 2011. Promoting native vegetation and diversity in exotic annual grass infestations. Restoration Ecology. 19(2): 159-165. [93364].

20. Davies, K. W.; Madsen, M. D.; Hulet, A. 2017. Using activated carbon to limit herbicide effects to seeded bunchgrass when revegetating annual grass-invaded rangelands. Rangeland Ecology and Management. 70(5): 604-608. [93682].

*21. Davies, K. W.; Madsen, M. D.; Nafus, A. M.; Boyd, C. S.; Johnson, D. D. 2014. Can imazapic and seeding be applied simultaneously to rehabilitate medusahead-invaded rangeland? Single vs. multiple entry. Rangeland Ecology and Management. 67(6): 650-656. [93671].

*22. Davies, Kirk W. 2010. Revegetation of medusahead-invaded sagebrush steppe. Rangeland Ecology and Management. 63(5): 564-571. [93363].

23. Davies, Kirk W.; Johnson, Dustin D. 2017. Established perennial vegetation provides high resistance to reinvasion by exotic annual grasses. Rangeland Ecology & Management. 70(6): 748-754. [92908].

*24. Davies, Kirk W.; Johnson, Dustin D.; Nafus, Aleta M. 2014. Restoration of exotic annual grass-invaded rangelands: Importance of seed mix composition. Invasive Plant Science and Management. 7: 247-256. [93672].

*25. Davies, Kirk W.; Nafus, Aleta M.; Johnson, Dustin D. 2013. Are early summer wildfires an opportunity to revegetate exotic annual grass-invaded plant communities? Rangeland Ecology & Management. 66(2): 234-240. [86945].

26. Davies, Kirk W.; Nafus, Aleta M.; Sheley, Roger L. 2010. Non-native competitive perennial grass impedes the spread of an invasive annual grass. Biological Invasions. 12: 3187-3194. [93681].

27. Davies, Kirk W.; Sheley, Roger L. 2007. Influence of neighboring vegetation height on seed dispersal: Implications for invasive plant management. Weed Science. 55(6): 626-630. [70034].

28. Davy, Josh S.; Roche, Leslie M.; Robertson, Alexis V.; Nay, Dennis E.; Tate, Kenneth W. 2015. Introducing cattle grazing to a noxious weed-dominated rangeland shifts plant communities. California Agriculture. 69(4): 230-236. [93684].

*29. Davy, Josh; Dykier, Katherine. 2017. Longevity of a controlled burn's impacts on species composition and biomass in northern California annual rangeland during drought. Rangeland Ecology and Management. 70(6): 755-758. [93366].

30. De Lillo, Enrico; Vidovic, Biljana; Petanovic, Radmila; Cristofaro, Massimo; Marini, Francesca; Auge, Matthew; Cvrkovic, Tatjana; Babic, Emilja; Mattia, Chiara; Lotfollahi, Parisa; Rector, Brian G. 2018. A new Aculodes species (Prostigmata: Eriophyoidea: Eriophyidae) associated with medusahead, Taeniatherum caput-medusae (L.) Nevski (Poaceae). Systematic and Applied Acarology Society. 23(7): 1217-1226. [93685].

31. DiTomaso, J. M.; Johnson, D. W., eds. 2006. The use of fire as a tool for controlling invasive plants. Cal-IPC Publication 2006-01. Berkely, CA: California Invasive Plant Council. 49 p. [90711].

32. DiTomaso, Joseph M.; Brooks, Matthew L.; Allen, Edith B.; Minnich, Ralph; Rice, Peter M.; Kyser, Guy B. 2006. Control of invasive weeds with prescribed burning. Weed Technology. 20(2): 535-548. [63695].

33. DiTomaso, Joseph M.; Kyser, Guy B.; George, Melvin R.; Doran, Morgan P.; Laca, Emilio A. 2008. Control of medusahead (Taeniatherum caput-medusae) using timely sheep grazing. Invasive Plant Science and Management. 1(3): 241-247. [93368].

*34. DiTomaso, Joseph M.; Kyser, Guy B.; Miller, Jessica R.; Garcia Sergio; Smith, Richard F.; Nader, Glenn; Connor, J. Michael; Orloff, Steve B. 2006. Integrating prescribed burning and clopyralid for the management of yellow starthistle (Centaurea solstitialis). Weed Science. 54: 757-767. [64333].

**35. DiTomaso, Joseph M.; Kyser, Guy B.; Oneto, Scott R.; Wilson, Rob G.; Orloff, Steve B.; Anderson, Lars W.; Wright, Steven D.; Roncoroni, John A.; Miller, Timothy L.; Prather, Timothy S.; Ransom, Corey; Beck, K. George; Duncan, Celestine; Wilson, Katherine A.; Mann, J. Jeremiah. 2013. Medusahead. In: Weed control in natural areas in the western United States. Davis, CA: University of California, Weed Research and Information Center: 392-394. [93675].

Consecutive annual prescribed fires can control medusahead in low-elevation, warm-winter sites (e.g., California's Central Valley and Foothills) in the short term. However, prescribed fires in high-elevation, cool-winter sites usually fail to control medusahead because fuels are less abundant and less continuous, making sites difficult to burn, and because native plants are not adapted to frequent fire.

**36. DiTomaso, Jospeh M. 2006. Control of invasive plants with prescribed fire. In: DiTomaso, J. M.; Johnson, D. W., eds. The use of fire as a tool for controlling invasive plants. Cal-IPC Publication 2006-01. Berkeley, CA: California Invasive Plant Council: 7-18. [90714].

Medusahead abundance can be reduced in annual grasslands using properly timed prescribed fire (while seeds are still in seedheads), but repeated burning or other control methods following the initial fire are needed to slow medusahead recovery.

37. Gornish, E. S.; James, J. J. 2016. Interactions among habitat, management, and demography for an invasive annual grass. Plant Ecology. 217: 1247-1258. [93686].

*38. Hughes, Charles C., IV. 2003. The effects of fall burning on two northern California perennial bunchgrass communities. East Lansing, MI: Michigan State University. 66 p. Thesis. [93370].

39. James, J. J.; Davy, J.; Doran, M. P.; Becchetti, T.; Brownsey, P.; Laca, E. A. 2017. Targeted grazing impacts on invasive and native plant abundance change with grazing duration and stocking density. Rangeland Ecology and Management. 70(4): 465-468. [93687].

**40. James, J. J.; Gornish, E. S.; DiTomaso, J. M.; Davy, J.; Doran, M. P.; Becchetti, T.; Lile, D.; Brownsey, P.; Laca, E. A. 2015. Managing medusahead (Taeniatherum caput-medusae) on rangeland: A meta-analysis of control effects and assessment of stakeholder needs. Rangeland Ecology and Management. 68(3): 215-223. [93371].

This publication includes a systematic review and meta-analysis of 22 studies on the effects of control methods on medusahead abundance in annual grasslands and shrub-steppe. It identifies key knowledge gaps including a lack of long-term studies that report medusahead response to fire and other control methods beyond 3 years after treatment.

**41. Johnson, D. D.; Davies, K. W. 2012. Medusahead management in sagebrush-steppe rangelands: Prevention, control, and revegetation. Rangelands. 34(1): 32-38. [93372].

This synthesis examines methods for limiting medusahead establishment and spread in sagebrush-steppe communities. A combination of prescribed burning in fall followed by application of imazapic soon after, and seeding of desirable species in fall 1 year later was recommended to control medusahead and revegetate desirable perennial grasses on medusahead-infested sites. However, long-term response (>3 years posttreatment) of medusahead to this regime had not been reported as of this writing (2012).

42. Kennedy, Ann C. 2018. Selective soil bacteria to manage downy brome, jointed goatgrass, and medusahead and do no harm to other biota. Biological Control. 123: 18-27. [93688].

*43. Kyser, G. B.; DiTomaso, J. M.; Doran, M. P.; Orloff, S. B.; Wilson, R. G. 2007. Control of medusahead (Taeniatherum caput-medusae) and other annual grasses with imazapic. Weed Technology. 21(1): 66-75. [93666].

44. Kyser, Guy B.; Creech, J. Earl; Zhang, Jimin; DiTomaso, Joseph M. 2012. Selective control of medusahead (Taeniatherum caput-medusae) in California sagebrush scrub using low rates of glyphosate. Invasive Plant Science and Management. 5(1): 1-8. [93690].

45. Kyser, Guy B.; DiTomaso, Joseph M.; Davies, Kirk W.; Davy, Josh S.; Smith, Brenda S. 2014. Medusahead management guide for the western United States. Davis, CA: University of California, Weed Research and Information Center. 68 p. [93850].

*46. Kyser, Guy B.; Doran, Morgan P.; McDougald, Neil K.; Orloff, Steve B.; Vargas, Ronald N.; Wilson, Robert G.; DiTomaso, Joseph M. 2008. Site characteristics determine the success of prescribed burning for medusahead (Taeniatherum caput-medusae) control. Invasive Plant Science and Management. 1(4): 376-384. [81113].

47. Kyser, Guy B.; Peterson, Vanelle F.; Davy, Josh S.; DiTomaso, Joseph M. 2012. Preemergent control of medusahead on California annual rangelands with aminopyralid. Rangeland Ecology and Management. 65(4): 418-425. [93689].

*48. Kyser, Guy B.; Wilson, Robert G.; Zhang, Jimin; DiTomaso, Joseph M. 2013. Herbicide-assisted restoration of Great Basin sagebrush steppe infested with medusahead and downy brome. Rangeland Ecology and Management. 66(5): 588-596. [93374].

49. Louhaichi, Mounir; Carpinelli, Michael F.; Richman, Lesley M. Johnson, Douglas E. 2012. Native forb response to sulfometuron methyl on medusahead-invaded rangeland in eastern Oregon. The Rangeland Journal. 34: 47-53. [93691].

50. Malmstrom, Carolyn M.; Butterfield, H. Scott; Planck, Laura; Long, Christopher W.; Eviner, Valerie T. 2017. Novel fine-scale aerial mapping approach quantifies grassland weed cover dynamics and response to management. PLoS ONE. 12(10): 1-28. [93692].

*51. Maret, Mary P.; Wilson, Mark V. 2005. Fire and litter effects on seedling establishment in western Oregon upland prairies. Restoration Ecology. 13(3): 562-568. [54923].

52. Merriam, Kyle E.; Keeley, Jon E.; Beyers, Jan L. 2006. Fuel breaks affect nonnative species abundance in Californian plant communities. Ecological Applications. 16(2): 515-527. [62280].

53. Monaco, Thomas A.; Creech, J. Earl. 2004. Sulfosulfuron effects on growth and photosynthesis of 15 range grasses. Journal of Range Management. 57(5): 490-496. [50429].

*54. Monaco, Thomas A.; Osmond, Travis M.; Dewey, Steven A. 2005. Medusahead control with fall- and spring-applied herbicides on northern Utah foothills. Weed Technology. 19: 653-658. [93359].

55. Montes-Sanchez, Juan J.; Van Miegroet, Helga; Villalba, Juan J. 2017. Effects of energy supplementation and time on use of medusahead by grazing ewes and their lambs. Rangeland Ecology and Management. 70(3): 380-387. [93693].

56. Montes-Sanchez, Juan J.; Villalba, Juan J. 2017. Effects of early experience and alternative feeds on medusahead (Taeniatherum caput-medusae spp. asperum) intake by sheep. Applied Animal Behaviour Science. 188: 9-16. [93695].

**57. Nafus, Aleta M.; Davies, Kirk W. 2014. Medusahead ecology and management: California annual grasslands to the Intermountain West. Invasive Plant Science and Management. 7(2): 210-221. [93375].

This synthesis indicates that effective management strategies for medusahead differ between California annual grasslands and Intermountain West sagebrush-steppe, but in both ecosystems, medusahead management requires an integrated approach that both reduces medusahead abundance and increases abundance of desirable species. In California annual grasslands, high densities of other annuals may facilitate use of burning or grazing to reduce medusahead seed production and favor more desirable annual vegetation. In sagebrush-steppe, differences in phenology between medusahead and most desirable perennial grasses may facilitate the use of pre-emergent herbicides for control of medusahead.

*58. Osmond, Travis M. 2003. Effects of herbicides, burning, and reseeding of desirable forages for control of medusahead (Taeniatherum caput-medusae). Logan, UT: Utah State University. 51 p. Thesis. [93673].

59. Perkins, Lora B.; Hatfield, Gary. 2014. Competition, legacy, and priority and the success of three invasive species. Biological Invasions. 16: 2543-2550. [93696].

60. Reiner, Rich; Craig, Andrea. 2011. Conservation easements in California blue oak woodlands: Testing the assumption of livestock grazing as a compatible use. Natural Areas Journal. 31(4): 408-413. [83957].

61. Rinella, M. J.; Davy, J. S.; Kyser, G.B.; Mashin, F. E.; Bellows, S. E.; James, J. J.; Peterson, V. F. 2018. Timing aminopyralid to prevent seed production controls medusahead (Taeniatherum caput-medusae) and increases forage grasses. Inasive Plant Science and Management. 11(1): 61-68. [93842].

62. Rinella, Matthew J.; Bellows, Susan E.; Roth, Aaron D. 2014. Aminopyralid constrains seed production of the invasive annual grasses medusahead and ventenata. Rangeland Ecology and Management. 67(4): 406-411. [90655].

63. Rodhouse, Thomas J.; Irvine, Kathryn M.; Sheley, Roger L.; Smith, Brenda S.; Hoh, Shirley; Esposito, Daniel M.; Mata-Gonzalez, Ricardo. 2014. Predicting foundation bunchgrass species abundances: Model-assisted decision-making in protected-area sagebrush steppe. Ecosphere. 5(9): 16 p. [92793].

64. Ryals, Rebecca; Eviner, Valerie T.; Stein, Claudia; Suding, Katherine N.; Silver, Whendee L. 2016. Grassland compost amendments increase plant production without changing plant communities. Ecosphere. 7(3): 1-15. [93698].

65. Schantz, Merilynn C.; Sheley, Roger L.; James, Jeremy J.; Hamerlynck, Erik P. 2016. Role of dispersal timing and frequency in annual grass-invaded Great Basin ecosystems: How modifying seeding strategies increases restoration success. Western North American Naturalist. 76(1): 36-52. [90882].

*66. Schantz, Merilynn; Sheley, Roger; Hardegree, Stuart. 2019. Restoring perennial grasses in medusahead habitat: Role of tilling, fire, herbicides, and seeding rate. Rangeland Ecology and Management. 72(2): 249-259. [93376].

67. Sebastian, Derek J.; Nissen, Scott J.; Rodrigues, Juliana De Souza. 2016. Pre-emergence control of six invasive winter annual grasses with imazapic and indaziflam. Invasive Plant Science and Management. 9: 308-316. [93699].

68. Sforza, R.; Eken, C.; Hayat, R.; Widmer, T. L. 2004. First evaluation of Ustilago phrygica for the biological control of Taeniatherum caput-medusae (Triticeae). In: Proceedings of the XIIeme Colloque International Sur La Biologie Des Mauvaises Herbes; 31 August–2 September, 2004; Dijon, France. Paris, France: Association Nationale des Poles Territoriaux et des Pays: 407–412. [93845].

69. Shaw, Nancy L.; Monsen, Stephen B. 2000. Controlling annual grasses with OUST herbicide. In: Entwistle, P. G.; DeBolt, A. M.; Kaltenecker, J. H.; Steenhof, K., comps. Sagebrush steppe ecosystems symposium: Proceedings; 1999 June 21-23; Boise, ID. Publ. No. BLM/ID/PT-001001+1150. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Boise State Office: 66-70. [42721].

70. Sheley, R. L.; Bingham, B. S.; Svejcar, T. J. 2008. Crested wheatgrass defoliation intensity and season of use on medusahead invasion. Rangeland Ecology and Management. 61: 211-217. [93786].

*71. Sheley, Roger L.; Bingham, Brett S.; Davies, Kirk W. 2012. Rehabilitating medusahead (Taeniatherum caput-medusae) infested rangeland using a single-entry approach. Weed Science. 60(4): 612-617. [93377].

*72. Sheley, Roger L.; Carpinelli, Michael F.; Morghan, Kimberly J. Reever. 2007. Effects of imazapic on target and nontarget vegetation during revegetation. Weed Technology. 21: 1071-1081. [93674].

73. Sheley, Roger L.; Svejcar, Tony J. 2009. Response of bluebunch wheatgrass and medusahead to defoliation. Rangeland Ecology & Management. 62: 278-283. [75418].

74. Sheley, Roger L.; Vasquez, Edward A.; Chamberlain, Anna-Marie; Smith, Brenda S. 2012. Landscape-scale rehabilitation of medusahead (Taeniatherum caput-medusae)-dominated sagebrush steppe. Invasive Plant Science and Management. 5(4): 436-442. [93700].

75. Shinn, Sandra L.; Thill, Donald C. 2002. The response of yellow starthistle (Centaurea solstitialis), annual grasses, and smooth brome (Bromus inermis) to imazapic and picloram. Weed Technology. 16(2): 366-370. [93701].

76. Siegwart, M.; Bon, M. C.; Widmer, T. L.; Crespy, N.; Sforza, R. 2003. First report of Fusarium arthrosporioides on medusahead (Taeniatherum caput-medusae) and preliminary tests for host-specificity. Plant Pathology. 52: 416. [93702].

77. Spackman, C.; Stonecipher, C.; Panter, K.; Villalba, J. 2018. Exploring the fermentation kinetics of medusahead treated with glyphosate at different particle lengths. Journal of Animal Science. 96(Suppl. S3): 207. [93703].

78. Stein, Claudia; Hallett, Lauren M.; Harpole, W. Stanley; Suding, Katharine N. 2014. Evaluating ecosystem services provided by non-native species: An experimental test in California grasslands. PLoS ONE. 9(9): 1-7. [93704].

79. Stein, Claudia; Harpole, W. Stanley; Suding, Katharine N. 2016. Transitions and invasion along a grazing gradient in experimental California grasslands. Ecology. 97(9): 2319-2330. [93705].

80. Stonecipher, C. A.; Panter, K. E.; Villalba, J. J. 2016. Effect of protein supplementation on forage utilization by cattle in annual grass-dominated rangelands in the Channeled Scablands of eastern Washington. Journal of Animal Science. 94: 2572-2582. [93706].

81. Stonecipher, Clinton A. 2015. Chapter 5: Seeding medusahead-invaded rangeland following mechanical disturbance on the Channeled Scablands of eastern Washington. In: Mitigation of medusahead (Taeniatherum caput-medusae) through grazing and revegetation on the Channeled Scablands of eastern Washington. Logan, UT: Utah State University. Dissertation: 110-130. [93838].

82. Stonecipher, Clinton A. 2015. Mitigation of medusahead (Taeniatherum caput-medusae) through grazing and revegetation on the Channeled Scablands of eastern Washington. Logan, UT: Utah State University. 167 p. Dissertation. [93711].

83. Stonecipher, Clinton A.; Panter, Kip E.; Jensen, K. B.; Rigby, Craig W.; Villalba, Juan J. 2017. Revegetation of medusahead-invaded rangelands in the Channeled Scablands of eastern Washington. Rangeland Ecology and Management. 70(3): 388-395. [93707].

*84. Stubbs, Michelle M. 2001. Time-based nitrogen availability and risk of Taeniatherum caput-medusae (L.) Nevski invasion in central Oregon. Corvallis, OR: Oregon State University. 93 p. Thesis. [43177].

*85. Sweet, Sara B; Kyser, Guy B.; DiTomaso, Joseph M. 2008. Susceptibility of exotic annual grass seeds to fire. Invasive Plant Science and Management. 1(2): 158-167. [81071].

86. USDA, NRCS. 2019. The PLANTS Database, [Online]. U.S. Department of Agriculture, Natural Resources Conservation Service, National Plant Data Team, Greensboro, NC (Producer). Available: https://plants.usda.gov/. [34262].

87. Uselman, Shauna M.; Snyder, Keirith A.; Leger, Elizabeth A.; Duke, Sara E. 2014. First-year establishment, biomass and seed production of early vs. late seral natives in two medusahead (Taeniatherum caput-medusae) invaded soils. Invasive Plant Science and Management. 7(2): 291-302. [93378].

88. Uselman, Shauna M.; Snyder, Keirith A.; Leger, Elizabeth A.; Duker, Sara E. 2015. Emergence and early survival of early versus late seral species in Great Basin restoration in two different soil types. Applied Vegetation Science. 18: 624-636. [93708].

89. Wagner, Joseph A.; Delmas, Richard E.; Young, James A. 2001. 30 years of medusahead: Return to Fly Blown-Flat. Rangelands. 23(3): 6-9. [38069].

90. Widmer, T. L.; Sforza, R. 2004. Exploration for plant pathogens against Taeniatherum caput-medusae (medusahead ryegrass). In: Cullen, J. M.; Briese, J. T.; Kriticos, D. J.; Lonsdale, W. M.; Morin, L.; Scott. J. K., eds. Proceedings of the XI International Symposium on Biological Control of Weeds; 27 April–2 May 2003; Canberra, Australia. Canberra, Australia: CIRSO Entomology: 193-197. [93846].

91. Wu, Ruolai. 2017. A model to optimize grazing management for control of medusahead (Elymus caput-medusae) in California rangelands. Davis, CA: University of California Davis. 96 p. Thesis. [93709].

92. Young, Steve L. 2004. Natural product herbicides for control of annual vegetation along roadsides. Weed Technology. 18: 580-587. [93710].

Appendix

Table A1

Common and scientific names of plants mentioned in this annotated bibliography. For further information on fire ecology of these taxa, follow the highlighted links to FEIS Species Reviews. Nonnative species are indicated with an asterisk.	
Common name	Scientific name
Forbs	
alfalfa*	*Medicago sativa*
annual ragweed*	*Ambrosia artemisiifolia*
common yarrow	*Achillea millefolium*
curlycup gumweed	*Grindelia squarrosa*
Lewis flax	*Linum lewisii*
stork's bill	*Erodium* spp.
yellow starthistle*	*Centaurea solstitialis*
Graminoids	
barbed goatgrass*	*Aegilops triuncialis*
bluebunch wheatgrass	*Pseudoroegneria spicata*
blue wildrye	*Elymus glaucus*
bristly dogstail grass*	*Cynosurus echinatus*
bulbous bluegrass*	*Poa bulbosa*
cheatgrass* (also called downy brome [42])	*Bromus tectorum*
common wheat	*Triticum aestivum*
compact brome*	*Bromus madritensis*
crested wheatgrass*	*Agropyron cristatum*

desert wheatgrass*	*Agropyron desertorum*
Idaho fescue	*Festuca idahoensis*
jointed goatgrass*	*Aegilops cylindrica*
medusahead*	*Taeniatherum caput-medusae* (Synonyms used include *Taeniatherum caput-medusae* ssp. *asperum* [56] and *Elymus caput-medusae* [91])
purple needlegrass	*Nassella pulchra*
rattail sixweeks grass*	*Vulpia myuros*
ripgut brome*	*Bromus diandrus*
Roemer's fescue	*Festuca idahoensis* subsp. *roemeri*
Sandberg bluegrass	*Poa secunda*
Siberian wheatgrass*	*Agropyron fragile*
smooth brome*	*Bromus inermis*
soft brome*	*Bromus hordeaceus*
squirreltail	*Elymus elymoides*
Thurber needlegrass	*Achnatherum thurberianum*
timothy*	*Phleum pratense*
ventenata*	*Ventenata dubia*
wild oat*	*Avena fatua*
Shrubs	
basin big sagebrush	*Artemisia tridentata subsp. tridentata*
big sagebrush Bonneville big sagebrush Mojave big sagebrush snowfield big sagebrush basin big sagebrush	*Artemisia tridentata* *Artemisia tridentata subsp. × bonnevillensis* *Artemisia tridentata* subsp. *parishii* *Artemisia tridentata* subsp. *spiciformis*, *Artemisia tridentata* subsp. *tridentata*, *Artemisia tridentata* subsp. *vaseyana*, *Artemisia tridentata* subsp. *wyomingensis*,

mountain big sagebrush Wyoming big sagebrush xeric big sagebrush	*Artemisia tridentata* subsp. *xericensis*
forage kochia*	*Bassia prostrata*
low sagebrush alkali sagebrush gray low sagebrush Lahontan sagebrush	*Artemisia arbuscula* *Artemisia arbuscula* subsp. *longiloba* *Artemisia arbuscula* subsp. *arbuscula* *Artemisia arbuscula* subsp. *longicaulis*
mountain big sagebrush	*Artemisia tridentata* subsp. *vaseyana*
rubber rabbitbrush	*Ericameria nauseosa*
sagebrush	*Artemisia* spp.
Wyoming big sagebrush	*Artemisia tridentata* subsp. *wyomingensis*
Trees	
blue oak	*Quercus douglasii*
interior live oak	*Quercus wislizeni*
oak	*Quercus spp.*
western juniper	*Juniperus occidentalis*