Ventenata dubia, ventenata

2022

Ventenata clump in a ponderosa pine stand. Creative Commons photo by Matt Lavin.

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SUMMARY

This review summarizes the information that was available in the scientific literature as of 2022 on the biology, ecology, and effects of fire and control methods on ventenata in North America.

Ventenata is a nonnative, winter annual grass that is invasive in parts of the Pacific Northwest. It is most common in Palouse prairie, canyon grassland, sagebrush steppe, sagebrush scabland, juniper and ponderosa pine woodland, and dry mixed-conifer forest. Ventenata regenerates only from seeds. It typically germinates, emerges, and grows in fall, is dormant over winter, and resumes growth in spring. A small percentage (<10%) of seeds germinate in spring. Plants flower and produce seeds in spring or summer and die after seed set. A small percentage (<1%) of ventenata seeds may remain viable for up to 3 years, thus forming a short-term persistent soil seed bank. Ventenata may establish from these on-site seeds after fire. Animals may disperse ventenata seeds onto burns from off-site sources. The relative importance of on- or off-site seed sources to postfire establishment has not been documented. Postfire conditions that are favorable for ventenata seedling establishment include reduced vegetation cover and increased bare soil, although in some cases, ventenata seedling establishment and survival may be greater when ventenata litter is present, such as in dry years.

As of 2022, few studies were available on ventenata's response to fire. Studies were conducted from <1 year to 15 years after fire. Seven studies were in Palouse prairie, six in mixed-conifer forests, and one in sagebrush steppe. Overall, these studies found that ventenata can establish after fire. Most studies found that ventenata abundance was unaffected by fire, but some studies found that abundance increased or decreased. These studies suggest that time since fire, season of burning, prefire ventenata abundance, precipitation amount and timing, presence of other disturbances, and pre- and postfire management may affect ventenata's response to fire. In forests, reduction of canopy cover by fire appears to favor ventenata establishment and spread, while in Palouse prairie fire does not appear to affect ventenata abundance, which increased over time with and without burning.

Ventenata tends to dry out earlier than associated perennial grasses and remains highly flammable throughout the fire season. Ventenata invasion can increase fine fuel loads and continuity by establishing in typically bare interspaces between shrubs and perennial grasses, which can increase risk of fire spread in areas that historically had discontinuous fuels. Models suggest that ventenata invasion can increase fire severity, annual area burned, fire intensity, and burn probability, and researchers have hypothesized that a grass/fire cycle may establish in some communities invaded by ventenata, such as sagebrush steppe.

Because ventenata abundance is unlikely to decrease after fire and there is concern about damage to native plants, prescribed fire alone is not recommended to control ventenata in any plant community. Limited evidence suggests that prescribed fire combined with other control methods may help reduce ventenata abundance in the short-term. However, other methods, either alone or in combination, may be more effective than methods including fire. Preventing ventenata from establishing is critical and the most effective and least costly management method. Whatever method is used to control ventenata, repeated follow-up treatments are needed to prevent reestablishment.

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INTRODUCTION

FEIS Abbreviation

VENDUB

Common Names

ventenata
North Africa grass
North African wiregrass
softbearded oat grass
ventenatagrass
wiregrass

TAXONOMY

The scientific name of ventenata is *Ventenata dubia* (Leers) Coss. (Poaceae). It is the only species of *Ventenata* found in North America [13,15,57,76,93,122,158].

Common names are used throughout this Species Review. For scientific names of plants mentioned in this review and links to other FEIS Species Reviews, see table A1.

Synonyms

None

LIFE FORM

Graminoid

DISTRIBUTION AND PLANT COMMUNITIES

GENERAL DISTRIBUTION

Ventenata is native to North Africa, southern and central Europe, and western Asia [13,57,168]. Although invasive in parts of North America and introduced in other parts of Asia [105], it is rare [5,69,111,140], endangered [5], or extirpated [140] in parts of its native range in Africa and Europe. See Alomran et al. (2019) for a review of information on ventenata's distribution outside of North America [5]. Ventenata is nonnative in North America, where it has a disjunct distribution. In the West, it occurs from British Columbia and Alberta south to northern California and northern Utah. In the East, it occurs from Ontario east to New Brunswick and south to east-central Wisconsin and New York [185] (fig. 1). Genetic analysis of 51 invasive populations in the West indicated that ventenata was introduced multiple times, and different genotypes were introduced in separate locations [150].

Ventenata is particularly widespread and invasive in the Pacific Northwest (Oregon, Washington, and Idaho) [130,157] (fig. 2), especially in the Inland Northwest (eastern Oregon, eastern Washington, and northern and southwestern Idaho) [93,185]. It was first identified in Washington in 1952 [17] and had spread to Idaho by 1957. By the mid-1980s, it was noted as "abundant in a few localities" in canyon grasslands of west-central Idaho [176] and was present throughout the Pacific Northwest [29]. In 2001, its annual spread rate in the Pacific Northwest was estimated at 1.2 million ha/year (National Invasive Species Council 2001, cited in [140]). In the Blue Mountains ecoregion, ventenata populations with >20%

cover occurred on 378,000 ha in 2006 and 545,000 ha in 2017; an average increase of 15,200 ha/year [133]. It is less common in other parts of the West [120,130]. However, as of this writing (2022), substantial areas of potential habitat for ventenata occur throughout the West, especially in the Blue Mountains, Eastern Cascade Slopes/Foothills, and the Arizona/New Mexico Mountains ecoregions, indicating the potential for ventenata populations to spread to new areas [99].

Ventenata is incidental in the Great Lakes and Northeast [130]. It was first documented in the Great Plains in 2016 in Sheridan County, Wyoming [60].

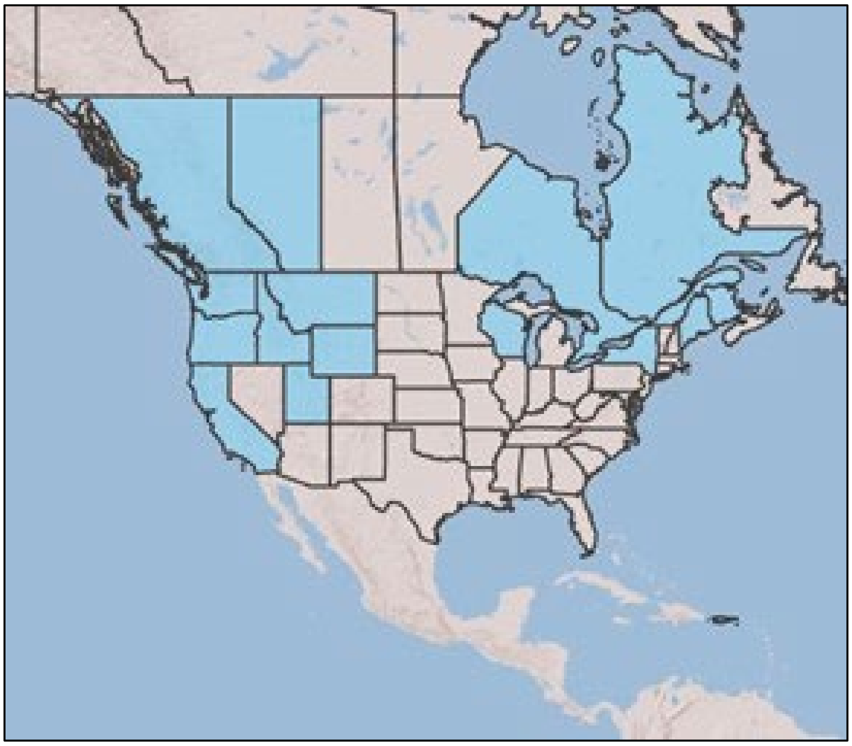

Figure 1—State- and province-level distribution of ventenata. Map courtesy of the U.S. Department of Agriculture, Natural Resources Conservation Service [185] [1 April 2021]. Ventenata also occurs in Nevada [5,55] and Nova Scotia [93].

States and provinces [5,93,120,150,185]
United States: CA, ID, ME, MT, NV, NY, OH, OR, UT, WA, WI, WY
Canada: AB, BC, NB, NS, ON, QC

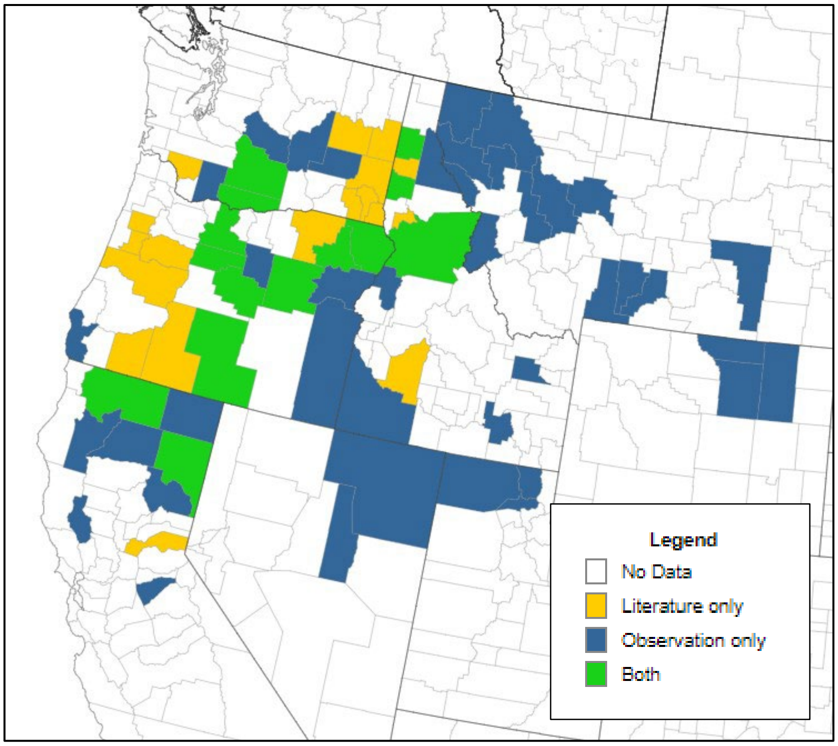

Figure 2—County-level distribution of ventenata in the western United States. Map courtesy of EDDMapS [55] [1 April 2022].

SITE CHARACTERISTICS

Ventenata grows in a variety of dry, open, often disturbed areas such as scablands[203] and along roadsides [13]. It is classified as an obligate upland species in the Columbia Basin of Washington [43]. In Palouse prairie and canyon grasslands of the Inland Northwest, ventenata can invade both dry and mesic or relatively wet areas. Although it does not invade the wettest grassland communities [90], it tends to prefer seasonally wet sites [91], such as those that are flooded in early spring but dry by late spring [29,126,147,168]. For example, ventenata can be dense in vernally moist swales on the Malheur National Forest, Oregon [171], and it occurs mostly in ephemerally wet microhabitats in sagebrush steppe on the Snake River Plain, including topographic features that retain water (e.g., seasonal streambeds) and areas that receive relatively more precipitation [91,138]. At Turnbull National Wildlife Refuge in eastern Washington, metrics indicating spring moisture abundance (e.g., standing water depth) were positively associated with ventenata cover [37,68]. Ventenata appears to initially establish on moist sites (i.e., seasonally wet areas) and then spread to drier sites, such as dry, southern and western aspects [29,90,91,132]. Across the Inland Northwest from 2008 to 2010, it spread from moist, low drainages and springs onto dry, shallow scablands [29].

Climate and Weather

Above-average precipitation and warm fall and winter temperatures may increase ventenata population abundance and spread. Annual precipitation in ventenata-invaded areas of the Pacific Northwest ranges from 350 to 1,120 mm/year [13,28,154]. On the Columbia Plateau, invasion rates are highest in the intermediate (300-450 mm) to high (480-600 mm) precipitation zones, where dry croplands interface with Palouse prairie and forests [155]. In low-elevation Wyoming big sagebrush steppe in John Day Fossil

Beds National Monument in eastern Oregon, the largest increase in ventenata cover was correlated with the wettest winter during 4 years [132]. In Mima mound prairie at Turnbull National Wildlife Refuge, ventenata was dense in 2012, a year with above-average precipitation in March (113.6 mm). Ventenata density was reduced by 150 stems/m^2 and cover was 60% lower the following year (2013), which had below-average precipitation in March (24.8 mm) [6]. A bioclimatic and phenology-based model found that ventenata populations with >20% cover in the Blue Mountains ecoregion were associated with average winter maximum temperatures above 5.5 °C, average fall maximum temperature above 6.5 °C, and total winter precipitation between about 100 and 220 mm. Additionally, ventenata spread was associated with an earlier green-up in spring [133], likely because it is a winter annual.

Topography

Ventenata occurs from near sea level to 1,800 m in the western United States [17,132,147,168]. It occurs at higher elevations than cheatgrass [96]. It is reported from 10 to 1,800 m in the Pacific Northwest [91,147], from 500 to 1,500 m in California [13], and from about 870 to 1,660 m in Montana [117]. In sagebrush steppe in the Blue Mountains and the Snake River Plain, ventenata occurred at elevations from about 900 to 1,660 m [91]. In the Blue Mountains ecoregion, ventenata established and spread most between 1,250 and 1,665 m [180]. Half of the populations that persisted from 2006 to 2017 were located between 1,091 and 1,285 m, and >40% of ventenata expansion occurred from 1,300 to 1,800 m [133]. Ventenata occurs from about 140 to 1,500 m in its native range [83,145,159], although elevational range in its native range is not well described.

Ventenata occurs on flat to steep sites [90,132] and on all aspects [147], although its association with aspect depends in part on location and plant community. In eastern Washington and western Idaho, it is most common on southern and western aspects [90,147]. In Palouse prairie of eastern Washington and western Idaho and canyon grasslands of western Idaho, ventenata was generally most abundant on shallow soils and southern to western aspects. In Palouse prairie, greater abundance of ventenata was also associated with moderate slopes and mid-elevations, while in canyon grasslands, greater abundance of ventenata was also associated with more rock, less bare ground, and steeper slopes [90]. In xeric, low-elevation Wyoming big sagebrush steppe at John Day Fossil Beds National Monument, ventenata occurred on all but the steepest southern aspects. It was most common on flat sites and on steep slopes with northern aspects, indicating an affinity for relatively mesic sites within xeric sagebrush steppe [132].

Soils

Ventenata typically grows in shallow soils [29,88,90,133,168]. Soils are often cobbly, gravelly, or stony [29,88,117,168]. Soil textures in its nonnative range include clays and loams [29,88,90,91,117,132,168]. In the Inland Northwest, it grows in clays and clay loams [29,88,91,132,168] and in loess soils deposited on plateaus [21]. In bluebunch wheatgrass-Sandberg bluegrass-largehead clover associations of the Blue Mountains, it occurs on southwestern aspects in very gravelly loam overlying very gravelly clay [88]. In canyon grasslands of Washington and Idaho, ventenata grows mostly in loams and silt loams, although ventenata cover was not related to clay, sand, or silt content [90]. However, in sagebrush steppe in southwestern Idaho and southeastern Oregon, ventenata cover was positively associated with clay content [7,91], while there was no association between ventenata cover and sand or silt content [91]. Clay soils may be important for ventenata in sagebrush steppe because they drain slowly and hold water near the surface, where it can be accessed by the shallow roots of ventenata [7,90] (see Botanical Description). Jones et al. (2020) hypothesized that the lack of association between ventenata and soil texture in canyon grasslands was because ventenata occurred in canyon grassland sites longer than in sagebrush steppe sites and thus has had the opportunity to spread to a wider variety of site types [90]. In Montana, ventenata grows in silt loam, cobbly loam, gravelly loam, silty clay, and stony loam soils [117].

In the Pacific Northwest, ventenata often grows in soils with basaltic parent material [21,30,88,180,196]. In Idaho fescue-onespike oatgrass associations of the Ochoco and other ranges of the Blue Mountains, for example, it grows in shallow soils overlying basalt. Such dry grasslands are considered highly invasible by ventenata [88]. In the northern Blue Mountains, ventenata dominates relatively deep soils on disturbed Mima mounds (distinct domes of topsoil surrounded by shallower, intermound soils) overlying basalt bedrock or alluvial substrates [30,196].

Ventenata appears to grow well in both nutrient-rich and nutrient-limited areas [117,180]. While some studies found an association between soils with low phosphorus [91,114,180] and/or potassium [91,114,117] and high ventenata cover, other studies found no relationship [90]. In pasture and grass-hay fields in the Pacific Northwest, soils with high ventenata cover (>50%) were low in phosphorous and potassium compared to soils with low ventenata cover (<25%) [114]. In sagebrush steppe communities in the Blue Mountains and the Snake River Plain, high ventenata cover was associated with low phosphorous concentration, low potassium concentration, and high clay content [91]. However, in canyon grasslands of Washington and Idaho, there was no relationship between ventenata cover and phosphorous or potassium concentrations [90]. Majeski (2020) stated that “Ventenata may be able to grow among a variety of nutrient environments and tolerate less than superior conditions, given the opportunity. If low nutrient areas are the only places available for ventenata to grow, it may be able to tolerate those conditions more so than high nutrient areas where there is strong vegetation competition” [117].

PLANT COMMUNITIES

In its native range, ventenata occurs in mesic grasslands, ephemeral wetlands, bunchgrass steppes, shrub-bunchgrass steppes, moist depressions in semidesert steppes [48,128,159], and oak forest-steppes [145]. In North America, ventenata grows in nonnative annual grasslands, native perennial grasslands, shrub steppes, savannas, woodlands, and open forests. It also occurs in pastures, hayfields, and croplands [17,51,190].

In the Pacific Northwest, ventenata is most common in Palouse prairie, canyon grasslands, sagebrush steppes, sagebrush scablands, juniper and ponderosa pine woodlands, and dry mixed-conifer forests [9,10,133]. In the Blue Mountains ecoregion, the area of land occupied by ventenata increased in 18 of 19 potential natural vegetation (PNV) subzones from 2006 to 2017 (table 1). The subzones with the largest increase in land area occupied by ventenata were moist meadow, dry Rocky Mountain lodgepole pine, riparian hardwood forest, dry white fir-grand fir, ponderosa pine-Rocky Mountain lodgepole pine, and scabland grass. In 2017, upland shrub, juniper woodland, xeric pine, and dry ponderosa pine subzones had the greatest area occupied by ventenata; and ventenata occupied the highest proportion of area in xeric pine (23.9%), montane shrub (15.7%), scabland grass (14.7%), and dry ponderosa pine (14.4%) subzones. Although the area of land occupied by ventenata in scabland grass is low compared with other subzones, the proportion of this subzone invaded by ventenata nearly doubled over the 11 years. This subzone has been considered relatively resistant to invasion by other nonnative invasive annual grasses [133]. In 2012 in the Wallowa Mountains in eastern Oregon, ventenata frequency was highest along roadsides (45%) followed by grassland shrub steppe (28%) and open mixed-conifer forest (16%). It did not occur in closed mixed-conifer forest or subalpine forest [9,10].

Table 1— Area of land occupied by ventenata in the Blue Mountains ecoregion (BME) in each of 19 potential natural vegetation (PNV) subzones where it occupied >1% of the subzone area in 2017. Table modified from Nietupski (2021) [133].

PNV subzones	2006		2017	
	Area of BME occupied by ventenata (km²)	Percent of subzone occupied by ventenata	Area of BME occupied by ventenata (km²)	Percent of subzone occupied by ventenata
Upland shrub	841.2	9.7	1,150.9	13.3
Juniper woodland	782.4	7.7	1,043.4	10.3
Xeric pine	705.1	17.1	984.3	23.9
Dry ponderosa pine	493.1	9.2	769.6	14.4
Dry Rocky Mountain Douglas-fir	288.7	3.8	463.6	6.1
Juniper steppe	271.9	8.7	363.3	11.6
Scabland shrub	125.1	7.9	174.3	11.0
Developed	101.6	3.3	170.7	5.6
Upland grass (including remnants of Palouse prairie)	40.0	10.3	53.9	13.8
Riparian shrub	34.4	8.1	57.4	13.5
Dry white fir-grand fir	28.0	0.5	58.3	1.1
Montane shrub	22.2	8.9	39.2	15.7
Ponderosa pine-lodgepole	2.7	3.9	6.0	8.5
Moist ponderosa pine	2.2	4.8	3.5	7.5
Ponderosa pine-white oak	0.9	4.9	0.5	2.6
Riparian hardwood forest	0.2	0.4	0.9	1.3
Dry Rocky Mountain lodgepole pine	<0.1	0.3	0.9	2.6
Scabland grass	<0.1	7.6	<0.1	14.4
Moist meadow	0	0	<0.1	6.9

Grasslands and Shrublands

Ventenata is invasive in Palouse prairie, canyon grassland, and sagebrush steppe communities, and is expanding into mixedgrass prairie at the interface between northern mixedgrass prairie and sagebrush steppe [9,10,51,70,90,116,155]. In the Pacific Northwest, it is rapidly spreading into and becoming dominant in sagebrush, bunchgrass, and former bunchgrass communities dominated by cheatgrass and/or medusahead [14,88,91,137,190,199]. It dominates many bluebunch wheatgrass, Idaho fescue, and onespike oatgrass communities of the Inland Northwest [9,10,78,88,111,188]. In southeastern Washington and western Idaho in 2018, mean ventenata cover was highest in the bluebunch wheatgrass habitat type (16.2%), followed by the low shrub habitat type dominated by common snowberry and Wood's rose (12.6%), and the Idaho fescue habitat type (9.7%) [90].

In eastern Oregon and western Idaho, ventenata is abundant in some mountain big sagebrush, scabland sagebrush, and low sagebrush stands [91,180]. It occurs in low sagebrush/Idaho fescue-bluebunch wheatgrass associations of the southern and central Blue and Ochoco mountains [88]. As of 2018, ventenata was strongly associated with scabland sagebrush-low sagebrush sites in the Blue Mountains ecoregion, while both dry Wyoming big sagebrush and relatively mesic mountain big sagebrush shrublands appeared resistant to ventenata invasion; however, ventenata was in a relatively early stage of invasion, and it may invade these communities with increased propagule pressure and residence time [180]. As of 2019, it was spreading in xeric, low-elevation Wyoming big sagebrush steppe at John Day Fossil Beds National Monument, especially on relatively mesic microsites [132].

Figure 3—Ventenata in Palouse prairie of eastern Washington. Wikimedia Commons photo by Matt Lavin.

Conifer Savannas, Woodlands, and Forests

Ventenata is invasive in open, dry ponderosa pine, dry Rocky Mountain Douglas-fir, and dry, mixed-conifer forests [9,10,66,100,133]. It is also widespread in western juniper woodlands [95,133]. In the Blue Mountains ecoregion, sites with high ventenata cover (>20%) were associated with ecotones between nonforested and forested areas (most of which was dominated by ponderosa pine) and with grass-shrub openings of the forest matrix (table 1) [133]. In this region, ventenata is strongly associated with western juniper-ponderosa pine woodlands and dry ponderosa pine-Rocky Mountain Douglas-fir forests [180].

Oregon White Oak Savannas

In the Willamette Valley, Oregon, ventenata occurs in Oregon white oak/Pacific poison-oak/California oatgrass-blue wildrye savannas [31]. It is common in the Oregon white oak/(Roemer's fescue, red fescue) wooded grassland association in the Puget Lowland and Willamette Valley in western Washington and Oregon, the eastern slope of the Washington Cascades, and the Columbia River Gorge in Washington; and in the Oregon white oak/Idaho fescue savanna and woodland association in Washington [58].

Riparian Communities

In the John Day River Basin, Oregon, ventenata occurs in riparian ponderosa pine/shrub communities [116], and it is spreading in the Blue Mountains ecoregion in riparian shrub and riparian hardwood forest (table 1) [133].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

BOTANICAL DESCRIPTION

This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Identification keys are available (e.g., [38,76]).

Ventenata is an annual grass. It typically grows from 15 to 46 cm tall [184,193], although some plants may reach 75 cm [193]. It has an open form, with a few stems (culms) that branch only at the root crown. Stems are spreading and often droopy, with a stiff, wiry texture [120,126,168]. Ventenata produces one to few tillers during its single growing season [147]. Leaves are rolled lengthwise or folded [126].

Figure 4—Ventenata has an open, sparse form. Creative Commons photo by Matt Lavin.

The inflorescence is an open, spreading to drooping, pyramid-shaped panicle (fig. 4) up to 41 cm long. The spikelets contain three to four florets. Florets are bisexual except for the lowest, which is usually staminate. Awns are long, up to 2.5 cm [51]. Awns on bisexual florets bend and twist as they mature (fig. 5) [13,15,76,193], while the awn on the staminate floret remains straight [193]. Identification can be tricky because the staminate floret tends to remain after the bisexual florets have broken off; at that stage, ventenata resembles oat species [38]. The fruit is a caryopsis [15,76].

Roots are shallow, from 2.5 to 5 cm deep [50,51,147]. Roots can be colonized by arbuscular mycorrhizal fungi (AMF), and ventenata is described as a facultative mycorrhizal plant, but more research is needed to understand how it interacts with and responds to AMF communities [153].

Figure 5—Upper florets with bent, twisted awns (center) that have broken away from the spikelets (outside). Creative Commons photo by Matt Lavin.

Raunkiaer Life Form [160]
Therophyte [159]

POPULATION STRUCTURE

Ventenata can occur as scattered individuals in early stages of invasion to near monocultures in patches of up to hundreds of hectares where it has been present for many decades [91]. Plant density and cover varies with timing and amount of annual precipitation (see Climate and Weather) and in response to fire on some sites (see Plant Response to Fire).

SEASONAL DEVELOPMENT

Ventenata is a winter annual [17,51,168,193]. It typically germinates, emerges, and grows in fall, becomes dormant with cool temperatures, remains dormant over winter, resumes growth in spring [2,17,51,111,168], flowers and produces seeds in spring or summer, and dies in summer [2,17,29,51,111,155,168] (table 2). Timing of germination and emergence depends on the amount and timing of precipitation and the timing and duration of warm temperatures, and may depend on amount of litter present [155,190] (see Seedling Emergence, Establishment, and Survival). Seeds typically germinate after the first fall rains [111], when temperatures are moderate to high [17,29,136,168,190] (see Germination). In the Inland Northwest, mean seedling emergence (50%) began after soil moisture rose above the permanent wilting point, which occurred between 6 October and 1 November across six sites and during 2 years. A small portion of seedlings emerge in spring [190]. Wallace et al. (2015) provide a model to predict the timing of seedling emergence, stem elongation, and flowering stages of ventenata in nonnative perennial grasslands, Idaho fescue and bluebunch wheatgrass rangelands, and timothy hayfields in the Inland Northwest [190].

Table 2—Phenological development of ventenata by location.

Area	Stage
Inland Northwest	2- to 3-leaf stage until mid-May, when stems elongate [155]
Pacific Northwest	Seedlings emerge October-April [190]
	Spring growth begins May-June [167,168]
	Nodes turn reddish-black May-June [126,167]
	Flowers mid-June-July [76,155]
	Seedheads produced in spring, 2-4 weeks after cheatgrass [147]
	Seed matures June-early July [155,167,168]
	Plants die June-August [167,168]
California	Flowers June-September [13]
Idaho, northwestern	Flowers May-August
	Plants die in July [111]
Idaho and Oregon	Flowers and sets seed 2-16 June [138]
Montana	Seedlings emerge in November. Seeds mature by 6 August [117]
Utah	Early vegetative stage 5 June [174]
Wisconsin	Near-flowering 14 June. Seeds mature and plants die by 5 July (Solheim and Judziewicz 1984, cited in [120])

Ventenata grows and develops more slowly than associated nonnative annual grasses. In Utah, ventenata and medusahead were still in the early vegetative stage in early June, when cheatgrass seedheads were beginning to emerge [174]. Ventenata seeds mature up to 1 month later than seeds of cheatgrass and other annual bromes across the range where the species overlap [29,120,147,155,168].

Ventenata dries out earlier in the season than native perennial bunchgrasses but later than associated nonnative annual grasses [96]. Seeds shatter and plants die in July or August [17,126,167,168]. Soil drying generally induces seed maturation [147] and plant death.

Ventenata color changes as it develops. Plants are bright green in early spring [167,168]. Nodes turn reddish- to purplish-black in late spring [126,195] (fig. 6). Plants become distinctly shiny when flowering and developing seedheads [50,168], then turn silvery-green before they dry and senesce [167]. They senesce and turn tan when soil dries, usually in late summer [167,168].

Figure 6—Nodes on ventenata stems turn reddish-black in late spring when flowers are developing. Photo by Pamela Scheinost, U.S. Department of Agriculture, Natural Resources Conservation Service, Pullman Plant Materials Center.

REGENERATION PROCESSES

Ventenata is an annual. It regenerates only from seeds [193].

Pollination and Breeding System

Ventenata is primarily self-pollinating [150].

Seed Production

Greenhouse experiments indicate vernalization is necessary for seedhead production, although data were not provided [147].

Ventenata produces 15 to 35 [29,147,168] or up to 50 [17] seeds/plant. In a garden study, ventenata plants produced up to 43,429 seeds/m^2 [190].

Seed Dispersal

Seeds drop near the parent plant when ripe [50,51]. Seeds are also dispersed by animals, including humans. The bent, twisted awns easily catch onto fur, feathers, clothing, and machinery. Ventenata seeds often disperse along roadways and other travel corridors [111,126,168] (see Successional Status) and in hay [168,190]. Once dispersed, awns unwind and "self-bury" or drill into soil [147,193]. Moisture accelerates unwinding of awns and seed burial [147].

Seed Banking

Ventenata has a short-term persistent soil seed bank [164]. A small percentage (<1%) of seeds stay viable in the seed bank for up to 3 years, although most germinate in the first year after dispersal [29,155,190]. Near Pullman, Washington, 82% and 79% of seeds germinated after 30 days of burial at 2 and 8 cm deep, respectively. Germination of seeds buried at 2-cm deep dropped to <1% after 13, 25, and 37 months of burial, and to 0% after 49 months. No seeds buried at 8 cm deep germinated after 13, 25, 37, or 49 months [190,192].

Density of ventenata in the soil seed bank may be high. In the bluebunch wheatgrass-sand dropseed-purple threeawn association in Hells Canyon National Recreation Area in northeastern Oregon, density of ventenata seeds averaged 2,292 seeds/m^2 where ventenata cover averaged 10.5% [19].

Soil seed bank density and composition (in the top 5 cm) and their response to drought differed between a low sagebrush community and a silver sagebrush community in southeastern Oregon, where nonnative annual grasses (ventenata and Japanese brome) together comprised 29% and 25% relative aboveground cover, respectively. Although cover of individual species was not given, ventenata was more common in the low sagebrush community, where nonnative annual grasses comprised 58% of the soil seed bank, and ventenata accounted for 99% of those seeds. After 3 years of experimentally induced drought, nonnative annual grass seed density (likely mostly ventenata) increased, and overall seed diversity and evenness decreased, while total seed density, total nonnative seed density, and native forb seed density were not different between drought and control plots. In the silver sagebrush community, nonnative annual grasses comprised 55% of the soil seed bank, and ventenata accounted for 67% of those seeds. Drought did not affect nonnative annual grass seed density, native forb seed density, total seed density, seed diversity, or seed evenness, but nonnative forb seed density was reduced in drought plots. Nonnative annual grass seed density did not differ between interspace and shrub microsites in either plant community. Differences in nonnative annual grass response to drought between the two sites may be attributed to differences in plant community composition, structure, or productivity; soil texture; or soil organic matter content [141].

Germination

Ventenata has a prolonged germination period, germinating mostly in fall but also in spring (see Seasonal Development). Warm and moist soils are important for germination in the field [190]. Maximum ventenata germination occurs at moderate to high fall temperatures (maximum germination from about 14 °C to at least 29 °C) and ventenata plants go dormant with cool temperatures [17,29,136,168,190]. Seeds typically germinate after the first fall rains [111]. According to Prather (2019), about 25 mm of rain is required to stimulate germination [156]. While suitable moisture and temperature conditions typically occur in fall and most seeds germinate then, dry conditions and low temperatures in fall can impose secondary dormancy and spring seedling emergence [190]. Less than about 10% of seeds germinate in spring [156].

Fresh ventenata seeds are apparently not germinable; a period of dry after-ripening is required for germination. In the laboratory, seeds in dry storage required at least 30 days of dry after-ripening before germination. Germination rates were highest (71%) after 90 days, compared to 23% after 30 days. After ripening, germination can occur over a wide range of temperatures (8.6 °C up to at least 29.2 °C). In a laboratory, temperatures for optimum germination (i.e., maximum germination in the shortest time) ranged from 23.3 to 29.2 °C. At these temperatures, cumulative germination ranged from 76% to 99%, and mean time to germination ranged from 7 to 13 days [190]. In another laboratory experiment, Northam (1986) reported the highest germination (93%) at 18 °C, compared to 50% at 28 °C and 24% at 8 °C. The time required to achieve 75% germination was 6 days at 18 °C, 10 days at 28 °C, and 13 days at 8 °C [136]. In the laboratory, seeds prechilled to 5 °C had about 30% germination compared to 85%

germination for seeds with no prechilling [29,190]. If soils become too cold before fall rains occur, seeds will not germinate, and secondary dormancy may be induced [190].

In the field, ventenata seeds germinate about 2 weeks later than cheatgrass [147,154]. In a laboratory, it took a mean of 15 days for ventenata to achieve 75% germination, compared to 5 days for cheatgrass and 18 days for medusahead [136].

Seedling Emergence, Establishment, and Survival

Although most ventenata germination and seedling emergence occurs in fall, some seedlings emerge in spring [190]. Predictive models based on observations from hay fields, nonnative perennial grasslands, and native bluebunch wheatgrass and Idaho fescue rangelands across a 300-km latitudinal gradient in eastern Washington, northeastern Oregon, and northern Idaho suggested that 35 to 90 growing degree days were required to reach 50% mean cumulative ventenata seedling emergence across sites. This corresponded to calendar dates from 18 October to 18 November across sites and years. An estimated 50 to 127 growing degree days were required to reach 95% mean cumulative seedling emergence and corresponded to calendar dates from 23 October to 10 April, indicating that some emergence occurred in spring. Spring emergence ranged from 0 to 13% of total emergence per year, and it was negligible in nonnative perennial grasslands, greatest in hay fields, and differed between years in rangelands. Differences in soil moisture and sites and years likely contributed to differences in cumulative seedling emergence to 95% [190].

While ventenata establishes on bare soil [88,111,179] (see Successional Status), and ventenata abundance is often positively associated with bare soil [90,180], ventenata emergence and survival may be higher on sites with ventenata litter than on sites with bare soil, especially during relatively dry years [190,192]. Ventenata seedling emergence and survival were greater under thick litter layers than on bare soil in a 2-year study near Pullman, Washington, although results differed between years. In the first year, emergence and survival rates (i.e., seedling density) were higher for ventenata sown under litter than in the no-litter control, and higher with thick litter (392 g/m^2) than thin litter (98 g/m^2). In the second year, ventenata emergence was higher in thick-litter plots, but it was similar between thin-litter plots and no-litter control plots. Initial seedling survival was similar among both treatments and controls in the second year; however, flowering plant densities were greater in thick-litter plots than in the no-litter control, indicating greater over-winter mortality without litter. The authors attributed differences between treatments to the effects of litter in mediating soil moisture and temperature in the upper soil profile, which would have more of an effect in drier (or colder) years. For example, greater cumulative precipitation in the second year resulted in similar soil moisture conditions with thin litter and without litter and thus might explain the lack of treatment effect [190]. In contrast, ventenata establishment in scabland sagebrush flats, low sagebrush steppe, and wet meadows on the Ochoco National Forest was similar on plots with litter and aboveground biomass removed and on paired, untreated control plots in 2019–2020. The authors suggest that belowground interactions (e.g., arbuscular mycorrhizae fungi), along with dispersal and propagule pressure, may contribute more to ventenata invasion than the absence of litter and aboveground biomass on these sites [179].

Plant Growth

Ventenata grows best on relatively moist sites (see Site Characteristics). For example, among three sites along a productivity gradient on the Ochoco National Forest, mean ventenata height was lowest in scabland sagebrush flats (which had the lowest moisture availability and plant productivity), intermediate in low sagebrush steppe (which had intermediate moisture availability and plant productivity), and greatest in wet meadows (which had the highest moisture availability and plant productivity). On average, ventenata was 140% taller in wet meadows than in scabland sagebrush flats, and 120% taller in wet meadows than in low sagebrush steppe [179].

Cheatgrass and medusahead generally have greater aboveground and belowground biomass than ventenata when grown under similar conditions [14,85,86]. For example, among ventenata, cheatgrass, and medusahead, ventenata had the lowest whole plant and root biomass under two different watering regimes (small-frequent and large-infrequent). Its whole plant and root biomass did not differ between watering regimes, suggesting that total cumulative soil moisture may be relatively more important to ventenata growth than timing and intensity of precipitation [14]. In another study, ventenata shoot and root biomass were lower than that of cheatgrass across climate (current (2018) and predicted future (2100)) and competition (grown alone and with each other) treatments; however, ventenata seedlings allocated relatively more growth to roots than cheatgrass (i.e., had a higher root:shoot ratio) across both climate treatments. This suggests that ventenata may have a competitive advantage for soil resources in current and future climates [71] (see Management Under a Changing Climate).

Soil microbes may favor ventenata growth. Ventenata above- and belowground biomass, shoot height, and number of leaves and tillers per plant were higher when grown with field soil inoculum collected from Bozeman, Montana (both ventenata-invaded and uninvaded soils), compared to sterilized greenhouse soil. This suggests that naturally-occurring soil microbes may facilitate ventenata growth at some locations [117].

Vegetative Regeneration

Ventenata does not regenerate vegetatively, but it may produce tillers. Tillers generally resprout if cut before soil dries [147].

SUCCESSIONAL STATUS

Shade Tolerance

Ventenata grows on open to partially closed sites [10,41,67,100,180], but does not appear to be invasive under closed canopies. In the Blue Mountains ecoregion, ventenata invaded both burned and unburned plots in shrubland, forest scabland, woodland, and dry forest with a wide range of understory (up to 150%) and overstory canopy cover (up to 50%) values. However, the most heavily invaded plots (those with >75% ventenata cover) were recently burned (1-4 years prior) and had <50% understory cover and <20% canopy cover [180]. Along an elevational gradient encompassing a range of plant communities from low-elevation bunchgrass and sagebrush steppe to midelevation mixed-conifer forests to subalpine spruce-fir forests in the Wallowa Mountains of northeastern Oregon, ventenata presence was associated with open tree canopies [10]. In savannas and woodlands in Oregon, ventenata occurs in open to lightly shaded areas, especially after tree cutting [66,95]. In mixed-conifer forests of Oregon, it can dominate the herb layer on sites with a relatively open canopy (up to about 40% canopy cover). These forests often occur in mosaics with grasslands (unpublished data cited in [100]). Reduction of canopy cover after fire appeared to favor ventenata establishment and spread in forests in the Blue Mountains ecoregion [134].

Succession

Ventenata establishes and can replace native grasses on both disturbed and relatively undisturbed sites [11,147] (see Impacts), but disturbance can facilitate ventenata establishment and spread and exacerbate impacts to native plant communities [181]. Ventenata can also replace other nonnative annual grasses [14,136,199]. It can establish on bare soil, and disturbances that reduce vegetation and expose bare soil appear to favor ventenata establishment in some areas [88,111]. Disturbances that may favor ventenata establishment and spread include fire (e.g., [41,65]) (see Plant Response to Fire), heavy grazing [88], other animal activity (e.g., burrowing) [30,41], drought [141], frost heaving, and flooding [2,111]. Fire suppression activities [181], road building, and construction [2,111] are additional disturbances that favor ventenata invasion. For example, digging hand lines for fire suppression may create establishment sites for ventenata and help it spread [181]. Along the Highway 95 corridor in northern Idaho, sites with exposed soil "always had ventenata and annual bromes" [111].

Ventenata can also establish and spread on undisturbed sites [11,56], such as on scabland sites that were undisturbed but bare prior to its establishment [67]. In Palouse prairie in the Zumwalt Prairie Preserve in northeastern Oregon, ventenata abundance increased over 7 years despite the absence of fire or major anthropogenic disturbances, such as heavy livestock grazing or cultivation [11]. In 2020, it had the highest cover of all nonnative invasive species in the preserve and was the second-most frequent species after annual bromes [56]. In the Blue Mountains ecoregion, ventenata was common on both burned and unburned plots in western juniper-ponderosa pine woodlands, dry ponderosa pine-Rocky Mountain Douglas-fir forests, and forest scabland (areas dominated by scabland sagebrush and low sagebrush and interspersed with dry forests) [180].

Biological soil crusts can interfere with the establishment of nonnative annual grasses, such as cheatgrass (e.g., [165]), and biological soil crust cover and nonnative annual grass cover can be negatively associated (e.g., [36,152,161]), especially in arid shrub-steppe ecosystems. However, this pattern is not apparent for ventenata. In Mima mound prairie at Turnbull National Wildlife Refuge, ventenata cover was up to 80% in intermound areas, “despite a diverse and abundant layer of biocrust species” and the researcher stated that “while maintaining an intact biological soil crust may be a successful management goal for limiting the invasion and spread of [cheatgrass], it appears this may not be the case for [ventenata]”. However, ventenata cover was negatively correlated with lichen cover during each of 3 years (r^2 = 0.12-0.66) and positively correlated with moss cover during 1 of the 3 years (r^2 = 0.17) [36]. This suggests that biological soil crust composition, which is influenced by time-since-disturbance (e.g., [1,18,49]), plays an important role in a site’s invasibility by ventenata. In sagebrush steppe in eastern Oregon and western Idaho, ventenata presence was positively associated with biological soil crust presence [91,138], but soil crust composition was not evaluated.

Ventenata is often found on the same sites as cheatgrass and medusahead (e.g., ([7,90,91,138,180]) and may replace them on some sites [14,28,88,91,137,190,199]. For example, ventenata has replaced cheatgrass in some bluebunch wheatgrass communities in the Blue Mountains [88], and it has replaced medusahead on some sites in eastern Washington and northern Idaho [137]. In sagebrush steppe in the Snake River Plain, high ventenata cover (>12.5%) was positively associated with the presence of medusahead and negatively associated with the presence of cheatgrass and several native shrubs. The researchers concluded that ventenata and medusahead share a similar niche, with both occupying moist microsites [91]. For more information on ventenata’s association with medusahead and cheatgrass, see Invasion Success.

FIRE ECOLOGY AND MANAGEMENT

IMMEDIATE FIRE EFFECTS

As of 2022, there was no published information on the immediate effect of fire on ventenata seeds or plants. Ventenata typically disperses its seeds and senesces in summer (Seasonal Development), which is during the peak fire season in the Pacific Northwest [61,104]. Fire that occurs when plants are green do not carry well and are likely to leave many surviving plants [156] (see Fire as a Control Agent).

Fire probably kills some ventenata seeds, especially if seedheads have not yet shattered. Seeds buried in soil are likely to survive because grass fires burn quickly and cause little soil heating [94,202]. Because ventenata buries its seeds [147] (see Seed Dispersal), it is likely that some seeds survive fire in the soil seed bank.

POSTFIRE REGENERATION STRATEGY

Ground residual colonizer (on site, initial community)
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources) [173]

FIRE ADAPTATIONS

Ventenata is an annual grass that produces abundant seeds (see Seed Production). It may establish after fire from seeds stored on-site in a short-term (up to 3 years) persistent soil seed bank (see Seed Banking) or from seeds dispersed onto burns from off-site sources by animals (see Seed Dispersal). However, although postfire establishment of ventenata has been documented in several studies (see Plant Response to Fire), the relative importance of on- or off-site seed sources has not been documented. Openings created by fire may favor ventenata germination and seedling establishment, especially in forests (see Successional Status). Reduced litter cover after fire may reduce ventenata seedling emergence and survival, especially in dry years (see Seedling Emergence, Establishment, and Survival), although this has not been documented in field studies (see Sagebrush Steppe: Postfire Seedling Establishment).

PLANT RESPONSE TO FIRE

As of 2022, few studies were available on ventenata's response to fire. Studies were conducted from <1 year to 15 years after fire, and most were in Palouse prairie remnants or other sites in the Palouse prairie region [6,41,65,114,162,163,175]. Studies were also conducted in mixed-conifer forests [54,100,127,133,180,203] and sagebrush steppe [7]. Overall, these studies found that ventenata can establish after fire [203] in both low-severity and high-severity burned patches [54]. Most studies found that ventenata abundance (cover, density, and biomass) was unaffected by fire [6,41,114,162,163,175], while some found postfire increases [65,203] or decreases [114].

Ventenata's postfire abundance may depend on time since fire [7], prefire ventenata abundance [114], precipitation amount and timing [6,7], site characteristics such as soil disturbance (e.g., northern pocket gopher activity) [41], and pre- and postfire management (e.g., tree harvesting or herbicide application) [7,203].

Fire may be more important to the establishment and spread of ventenata in forests than in grassland. In forests, reduction of canopy cover after fire appears to favor ventenata establishment and spread (see Ponderosa Pine and Mixed-conifer Forests: Postfire Abundance) [133], while in Palouse prairie ventenata abundance may be unaffected by fire (e.g., [162,163]) (see Palouse Prairie: Postfire Abundance).

Palouse Prairie

Postfire Seedling Establishment

Fire may promote ventenata establishment in invaded Palouse prairie, and effects may differ with season of burning, but information on these topics is lacking, and ventenata persists and spreads in Palouse prairie with and without fire (see Palouse Prairie: Postfire Abundance). In May, less than 1 year after prescribed burning and seeding of native and nonnative perennial grasses in Palouse prairie near Ritzville, Washington, annual grass seedling density (mostly ventenata), was higher on plots burned in summer (602 seedlings/m^2) or fall (296 seedlings/m^2) than on untreated control plots (166 seedlings/m^2) (table 4). See Integrated Management with Fire for more information, including ventenata response to other treatments [65].

Postfire Abundance

Once established, fire does not seem to consistently reduce ventenata abundance in the Palouse prairie region. One study suggests that ventenata seedling density may increase the first year after fire [65] and another suggests that it may decrease [114]. However, several other studies indicate that its abundance may be unchanged <1 year to 12 years after fire [6,41,114,162,163,175]. Postfire abundance may be influenced by precipitation timing and amount [6], prefire ventenata abundance [114], and interactions with other disturbances [41], although more data are needed on these topics.

One study in Mima mound prairie at Turnbull National Wildlife Refuge found that ventenata density and cover in three basalt intermound areas was not different between plots burned by fall prescribed fires (18 October or 8 November) and unburned control plots the following summer. Precipitation in March of that year was below average (24.8 mm), which likely resulted in decreased ventenata abundance on all plots [6]. For more information on this study, see Integrated Management with Fire.

Longer-term studies (up to 12 years after fire) conducted in the Zumwalt Prairie Preserve, Oregon, found that ventenata cover increased over time in Palouse prairie, with and without fire, suggesting that fire may not be a driving factor in the spread and increase of ventenata abundance in Palouse prairie [162,163,175]. One study compared ventenata abundance in June and July between burned (*n* = 12) and unburned (*n* = 44) plots. Burned plots were the result of either prescribed fires (*n* = 11) or wildfire (*n*= 1) and burned in 2005 (*n* = 3), 2006 (*n* = 1), 2007 (*n*= 5), 2012 (*n* = 1), 2013 (*n* = 1), or 2014 (*n* = 1); none of the plots was burned more than once. Plots were sampled in 2008, 2015, and 2016, 1 to 11 years after fire. There was not enough replication within years to test for effects of time-since-fire, so fire treatment response variables were pooled across all 12 plots. Plots were not excluded from livestock or wildlife grazing. Ventenata frequency and cover increased on all plots over time and were similar on burned and unburned plots in 2008, 2015, and 2016. The researchers concluded that neither fire nor precipitation appeared to be driving ventenata abundance, and they suggested that ventenata abundance may be influenced by time-since-fire or repeated fires, which they did not examine [163]. Another study on the Zumwalt Prairie Preserve found that ventenata frequency, cover, and density increased on all plots over time, and that ventenata cover was similar on plots burned under prescription (fall of 2006 and again in fall of 2016) and unburned plots in June and July of 2008 (2 years after fire), 2016 (10 years after the first fire and <1 year after the second fire), and 2018 (12 years after the first fire and 2 years after the second fire), on both grazed and ungrazed plots [162].

One study found that ventenata abundance after fire may depend on prefire abundance, but it did not appear to be affected by season of burning. In Palouse prairie dominated by nonnative grasses near Troy, Idaho, ventenata abundance was more consistently reduced in burned plots with high prefire ventenata cover (>50%) than in burned plots with low prefire ventenata cover (<25%). Plots with high prefire ventenata cover had lower ventenata cover (19.7%) and biomass (27.6 kg/ha) the following summer on fall-burned plots, and lower biomass (40.1 kg/ha) on spring-burned plots than unburned controls (45.3% and 83.9 kg/ha). Ventenata cover on spring-burned plots (35.3%) was similar to controls. On plots with low prefire ventenata cover, cover and biomass were similar between fall-burned (17.8% and 32.3 kg/ha), spring-burned (17.3% and 32.8 kg/ha), and control plots (31.5% and 29.1 kg/ha) (table 3). While postfire cover and biomass were lower, on average, on fall-burned than spring-burned plots with high prefire ventenata cover, differences were not significant between fall- and spring-burned plots regardless of prefire abundance [114]. For more information on this study, see Integrated Management with Fire.

Postfire abundance of ventenata may be higher on sites with disturbed soils. In Mima mound prairie at the Turnbull National Wildlife Refuge, ventenata density and cover were similar between burned and unburned plots almost 2 years after fall prescribed fire on sites where northern pocket gophers were absent. However, on plots that had high northern pocket gopher activity, ventenata density was about three times greater and cover was about six times greater on burned plots than unburned plots [41].

Sagebrush Steppe

Postfire Seedling Establishment

It is unclear whether ventenata establishes best with or without ventenata litter present, and effects of litter on seedling establishment and survival likely vary among sites and years [179,190]. Therefore, it is unclear whether fires that remove litter are more likely to reduce or enhance ventenata postfire establishment [114]. No postfire data are available on this topic, and evidence from other studies is inconclusive. For example, data from field plots in scabland sagebrush flats, low sagebrush steppe, and wet meadows on the Ochoco National Forest, Oregon, show no difference in ventenata establishment on plots with litter and aboveground biomass removed and untreated control plots [179], whereas data from garden plots near Pullman, Washington, suggest that litter may facilitate ventenata seedling establishment and survival [190] (see Seedling Emergence, Establishment, and Surival).

Postfire Abundance

After the 113-ha 2015 Soda Fire in the Owyhee Mountains in southwestern Idaho and southeastern Oregon, ventenata cover increased about 1.2%/year from 2016 to 2020 in sagebrush steppe communities previously invaded by cheatgrass. Ventenata cover was low overall but occurred in patches with high cover. These patches were smaller in postfire year 2 than in postfire year 1, probably due to herbicide application in each of those years. Patches then grew larger from postfire years 3 to 5, but they remained highly localized. After the fire, ventenata was positively associated with medusahead and negatively associated with cheatgrass. Prefire data were not available [7].

Figure 7—Continuous, dry ventenata in a big sagebrush stand. Creative Commons photo by Matt Lavin.

Ponderosa Pine and Mixed-conifer Forests

Postfire Abundance

Ventenata establishes after fire in dry ponderosa pine and mixed-conifer forests in the Blue Mountains, but studies are too few to determine long-term population dynamics. While some studies reported dense ventenata after fire [100,180] others suggest that while abundance may increase after fire, it is likely to remain low for up to 15 years [127,203]. On the Ochoco National Forest, ventenata dominated the understory of a ponderosa pine stand 5 years after a wildfire [100], and ventenata "heavily invaded" both burned and unburned dry conifer forests embedded in scablands throughout the Blue Mountains ecoregion [180], but no further details were provided in either study, so inference is limited. In a ponderosa pine-Rocky Mountain Douglas-fir/common snowberry community in the northern Blue Mountains, ventenata cover was higher in thinned and/or burned plots than in untreated control plots up to 17 years after treatments, although differences were not statistically significant, and ventenata appeared to be rare, overall [127,203]. Ventenata was not present in any plots before treatments. Fifteen years after prescribed fire and 17 years after thinning, its cover remained <1% in all treated plots and was 0.05% in untreated control plots [127].

Fire Severity

Both low-severity and high-severity burned patches appear to be susceptible to ventenata establishment. In dry mixed-conifer forest in the Blue Mountain ecoregion, 12 to 17 years after four large wildfires, cover and frequency of ventenata were similar between plots in patches of low-severity fire with surviving overstory tree canopy (i.e., "fire refugia") and plots in patches of high-severity, stand-replacement fire. Ventenata occurred in 12% of fire refugia plots and 10% of severely burned plots, and mean ventenata cover was 8% across all plots (range: 0.5-29%). Without prefire data, the researchers were unable to distinguish between ventenata populations that were present prior to fire and those that established after fire, or if ventenata cover changed following fire [54]. However, another study found that ventenata spread in the Blue Mountains ecoregion from 2006 to 2017 was predominantly in forested areas with high burn severity, particularly dry forest, mixed-conifer forest, and intermixed woodland/nonforest potential natural vegetation groups [133] (see Fuel and Fire Characteristics).

Figure 8—Patchy, dry ventenata in a ponderosa pine stand. Creative Commons photo by Matt Lavin.

FUEL AND FIRE CHARACTERISTICS

Ventenata is dry and remains highly flammable throughout the fire season [51,101], and its litter is relatively persistent. Dry ventenata stalks and litter decay more slowly than those of most associated grasses [9,51], likely due to ventenata's relatively high silica content when dry (2.7%) [51] (see Palatability and Nutrional Value).

Ventenata invasion increases fine fuel load and continuity by establishing in interspaces between shrubs and perennial bunchgrasses [181] (fig. 7), thus increasing the potential for fire spread in areas that historically had discontinuous fuels [50,51,62,100,143,181] (see Fire Regimes). For example, in scablands invaded by ventenata, fine fuel loads in communities with 50% to 80% ventenata cover were about 1,120 kg/ha—50 times higher than in uninvaded communities (about 22 kg/ha) [181]. Ventenata patches on previously barren scabland ridges contributed to fuel continuity and fire spread during the 2015 Corner Creek Fire in central Oregon. Firefighters noted that these ridges had converted from firebreaks to areas that were "quite receptive to fire" due to ventenata presence, and they witnessed rapid fire spread from these ventenata-invaded scablands into adjacent ponderosa pine woodlands, where it killed ponderosa pine, juniper, and sagebrush [67].

Some researchers have hypothesized that ventenata invasion may lead to more frequent fire, and that ventenata abundance would increase with each fire [88,151]. Frequent fire can reduce postfire abundance and diversity of native grasses and shrubs and further promote dominance of nonnative annual grasses, resulting in an annual grass/fire cycle [24,44,45], as has been documented in sagebrush ecosystems invaded by cheatgrass [12,22,59]. Because most sagebrush species cannot sprout after fire and recover slowly (e.g., [80,81,131,200]), sagebrush communities are unlikely to recover on sites with fire intervals less than about 30 years, and some require much longer fire-free intervals, depending on site characteristics [80,81].

Models suggest that changes in fuel characteristics brought about by ventenata invasion may increase fire intensity (flame length), fire severity, spread rate, burn probability, burn patch size, and annual area burned in some communities [62,133,177]. Custom fuel models developed from data collected on the Ochoco National Forest suggest that as ventenata biomass increases, flame lengths are also likely to increase in three ventenata-invaded ecosystems: scabland sagebrush, low sagebrush, and wet meadow. Increased flame lengths would likely result in more severe fires that are more difficult to control. In sparsely vegetated scabland sagebrush, any amount of ventenata invasion increased the modeled spread rate and flame lengths, and even a small increase in fine fuels resulted in greater fuel connectivity, which is likely to result in both larger and more severe fires than in uninvaded sites. In low sagebrush, a small increase in ventenata invasion is predicted to increase the spread rate and flame lengths on a previously uninvaded site more than a large increase on a previously invaded site. In wet meadows, increased spread rate is predicted only when ventenata is very abundant, likely because grass fuels in wet meadows are already horizontally continuous. However, once it becomes abundant, spread rate and flame lengths are predicted to greatly increase [62]. Simulated ventenata invasion in the Blue Mountains ecoregion increased mean annual area burned, burn probability, and flame lengths at three scales. At the ecoregion scale, ventenata invasion increased mean annual area burned by 2.6% relative to an uninvaded simulation, with the greatest impacts concentrated in dwarf shrublands. Mean burn probability in dwarf shrublands at the ecoregion scale was 15% higher, and probability of flame lengths exceeding 1.2-m tall was 15% higher in the invaded than the uninvaded simulation. Forest stands with 25% of their surrounding landscape invaded by ventenata had a 28% increase in burn probability and a 16% increase in the probability of high-intensity crown fire when burned (flame lengths >2.4 m). At the patch scale (patches ranged from 1.4 to 8,650 ha), burn probability and the probability of flame lengths exceeding 1.2-m tall increased in invaded patches relative to uninvaded patches. The difference between the invaded and uninvaded simulations increased as the size of the invaded patch increased [177].

Ventenata has spread and patch size has increased in burned forests, and severe fires may favor ventenata spread in forests [133]. In 2006 (9 years before the 44,000-ha Canyon Creek Complex of wildfires), ventenata occurred on 1,799 ha in the Blue Mountains ecoregion. Two years after these wildfires (2017), ventenata occurred on 5,667 ha in the ecoregion. From 2006 to 2017, mean ventenata patch size increased from 1.1 to 4.0 ha, while the number of patches decreased from 1,583 to 1,421. The mean minimum distance between patches decreased from 105 to 97 m, indicating that radial spread was more common than discontinuous spread. Severely burned areas tended to have the greatest ventenata spread; however, ventenata was spreading in unburned areas in the ecoregion, as well. Most spread occurred at relatively higher elevations (greater than about 1,300 m) and within dry forests and forest-nonforest ecotones. In dry forest and highly mixed forest-nonforest potential natural vegetation (PNV) groups, probability of ventenata occurrence increased more in large, burned areas than in similar areas that were not burned, apparently due to reduced canopy cover and ventenata propagule pressure from nearby open areas. These PNV groups also had relatively higher burn severity than other groups [133].

Ventenata invasion "may have negated some of the advantage" of fuel treatments (e.g., thinning and burning) that may have otherwise reduced fire behavior in forests relative to untreated or thinned-only treatments. On the 2015 Corner Creek Fire, the Incident Commander stated that the "treated areas almost always reduced fire behavior, but where there was ventenata it didn't matter, the fire just ran through the ventenata and kept going" [66].

FIRE REGIMES

Ventenata occurs in ecosystems that historically had varied fuel structures and fire regimes. Historically, dry mixed-conifer forests and ponderosa pine woodlands in the Blue Mountains had abundant perennial bunchgrasses and few shrubs in the understory and experienced mostly low- to moderate-severity surface fires [3,73,74], with mean historical fire intervals ranging from about 10 to 49 years [74,89,92,121,144]. Fire intervals in western juniper woodlands in the Columbia Basin were likely more variable, ranging from decades to centuries and included replacement, mixed, and surface fires [129]. These forests and woodlands were historically interspersed with areas of Palouse prairie dominated by perennial bunchgrasses, which historically had discontinuous surface fuels; and scablands that historically had either no surface fuels or extremely sparse surface fuels consisting of short-statured, herbaceous plants [52,101]. Modeled historical mean fire intervals range from about 21 to 35 years for Palouse prairie in the Columbia Basin and average about 250 years for Columbia Plateau scabland shrubland [110]. Historical fire intervals in sagebrush communities where ventenata invades varied widely, depending on site characteristics and plant community composition [81,82], but were typically longer than those in Palouse prairie and dry forests. Big sagebrush communities were codominated by widely spaced sagebrush and perennial bunchgrasses, and fuels were often limited and discontinuous [33,81,82]. Estimates of historical fire intervals in mountain big sagebrush communities range from a few decades to centuries [82], while those in Wyoming big sagebrush [81] and mixed-dwarf sagebrush [183] communities ranged from many decades or centuries to millennia. Fires in sagebrush communities were mostly patchy but high-severity [81,82].

Ventenata invasion is altering fuel structures, increasing fuel loads, and promoting fire spread in some scabland [67,181], Palouse prairie [96], and sagebrush steppe [62,100] communities by infilling interspaces between shrubs and bunchgrasses (see Fuel and Fire Characteristics); although the extent to which this is altering historical fire regimes of these communities is uncertain. Ventenata fuels can rapidly carry fire from invaded areas into adjacent grasslands and woodlands in the Blue Mountains ecoregion [96], and there is concern that this could promote either more frequent low- and moderate-severity fires in forests [181] or high-severity, stand-replacing fires that result in larger and more homogeneous burned patches on the landscape than occurred historically [62].

In sagebrush communities, researchers are concerned that ventenata may fuel frequent high-severity fires that kill sagebrush plants before they mature, which could lead to a conversion from sagebrush to herbaceous communities [62,100].

See these FEIS publications for further information on historical fire regimes in plant communities in which ventenata is sometimes invasive:

- Fire regimes of Columbia Plateau grasslands and steppe communities
- Fire regimes of conifer forests in the Blue Mountains
- Fire regimes of juniper communities in the Columbia and northern Great basins
- Fire regimes of northwestern montane and foothill grassland communities

- Fire regimes of mixed dwarf sagebrush communities
- Fire regimes of mountain big sagebrush communities
- Fire regimes of Wyoming big sagebrush and basin big sagebrush communities

Find additional fire regime information for the plant communities in which ventenata may occur in the United States by entering the species name in the FEIS "Advanced Search for Fire Regimes".

FIRE MANAGEMENT CONSIDERATIONS

Key Fire Management Considerations

- Ventenata invasion may alter fire behavior and spread.
- Preventing ventenata from establishing in burned areas is the most effective and least costly postfire management method.
- Ventenata seeds may remain in the soil seed bank for up to 3 years. Postfire monitoring and subsequent removal of seedlings is necessary to prevent establishment and spread.
- Prescribed fire alone is not likely to control ventenata.
- Prescribed fire integrated with other control methods may help control ventenata, but data are limited.
- After fire, seeding of desirable species may be necessary to prevent ventenata establishment where native vegetation is depleted.

Ventenata invasion can alter fuel characteristics, fire behavior, and fire spread [50,51,62,96,100,133,177,181]. Therefore, primary fire management considerations with regard to ventenata include fuels management (see Fuel and Fire Characteristics and Fire Regimes), preventing postfire establishment and spread (see below), and establishing and/or maintaining healthy and competitive desirable vegetation after fire (see Revegetation). Prescribed fire alone is not recommended to control ventenata in any plant community (see Fire as a Control Agent). Limited evidence suggests that fire may help reduce ventenata populations in the short-term when combined with other control methods (see Integrated Management with Fire), although due to potential postfire increases in ventenata abundance and/or damage to native plant communities, other control methods may be more effective (see Control).

Preventing Postfire Establishment and Spread

Ventenata may establish after fire from seeds in the soil seed bank [29,155,190] (see Seed Banking) or from seeds dispersed from off-site sources [111,126,168] (see Seed Dispersal), and fire may create conditions that are favorable for ventenata seedling establishment by creating openings [10,41,180], reducing vegetation cover [88,111] (see Successional Status), and exposing bare ground [88,102,111] (see Seedling Emergence, Establishment, and Survival).

Ventenata may establish, and possibly spread, after canopy opening disturbances in forests (see Shade Tolerance). For example, in dry mixed-conifer forests in the Blue Mountains, ventenata established after canopy thinning and prescribed burning. Although its abundance remained low (<1%) up to 15 years after treatments [127,203] (see Plant Response to Fire: Ponderosa Pine and Mixed-conifer Forests), posttreatment monitoring is recommended.

Preventing ventenata from establishing in weed-free burned areas and nearby unburned areas is critical for reducing its spread and is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and preventing dispersal of ventenata seeds into burned areas. In addition, the Washington State Noxious Weed Control Board recommends planting and seeding native herbaceous species after fire to limit ventenata establishment and spread [193] (see Revegetation). General recommendations for preventing postfire establishment and spread of invasive plants include [8,23,63,186]:

- Incorporate the cost of weed prevention and management into fire rehabilitation plans.
- Acquire restoration funding.
- Include weed prevention education in wildland fire training.
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities.
- Minimize the use of retardants that may alter soil nutrient availability, such as those containing nitrogen and phosphorus.
- Avoid areas dominated by high-priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases.
- Clean equipment and vehicles prior to entering burned areas.
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation.
- Monitor burned areas and areas of significant disturbance or traffic from management activity.
- Detect weeds early and eradicate before vegetative spread and/or seed dispersal.
- Eradicate small patches and contain or control large invasions within or adjacent to the burned area.
- Avoid use of fertilizers in postfire rehabilitation and restoration.
- Use only certified weed-free seed mixes when revegetation is necessary.

For detailed information, see the following publications: [8,23,63].

Fire as a Control Agent

As of 2022, prescribed fire alone is not recommended to control ventenata [167,168], although limited evidence suggests short-term population reductions may be possible when prescribed fire is combined with other control methods (see Integrated Management with Fire). Only one study found a reduction in ventenata cover and biomass after fire (<1 year after a fall prescribed fire) [114], whereas most studies found that ventenata abundance was either unaffected or increased after fire (see Plant Response to Fire). Wallace et al. (2015) proposed using prescribed fire to reduce the litter layer (thatch) created by ventenata and thus reduce ventenata seedling recruitment [190]; however, Ridder et al. (2022) “did not see any evidence to support this” and instead found that ventenata frequency, cover, and density were similar between burned and unburned plots at the Zumwalt Prairie Preserve [162]. A survey of land managers from the Pacific Northwest in 2011 indicated that they did not find fire to be an effective management tool for ventenata, and they described postfire dominance of ventenata [147].

Little information is available on the effects of season of burning on ventenata abundance. One study in nonnative perennial grasslands in the Palouse prairie region, found no difference in ventenata cover and biomass between fall- and spring-burned plots (table 3) [114] (see Plant Response to Fire: Palouse Prairie). Spring fires may be difficult in areas with dense ventenata. On plots with high prefire ventenata cover, spring ventenata fuels were densely matted and green and did not burn well [156]. In the Blue Mountains ecoregion, ventenata "invaded readily" after summer wildfires in landscapes with a mosaic of dry mixed-conifer forests and scablands, suggesting that burning in summer is not likely to control ventenata in these landscapes. Furthermore, burned-invaded sites were associated with lower native species diversity, species richness, and functional group cover than unburned-invaded sites, suggesting that prescribed fire during summer could reduce biodiversity and ecosystem function. This may be especially true in scablands dominated by scabland sagebrush and low sagebrush where burning coupled with invasion may initiate a state shift from shrub steppe to annual grassland [180] (see Fire Regimes).

Integrated Management with Fire

Few published studies on integrated management of ventenata with fire are available. While some sources suggest that fire may help reduce ventenata populations when combined with other control methods such as herbicides [28,29,193], one study found no effect of fire either alone or in combination with herbicide application and/or trampling [6]. Other methods, such as herbicides alone or herbicides followed by seeding, may be more effective than methods integrated with fire [29] (see Control).

Palouse Prairie

Studies are too few to generalize effects of integrated methods that include fire on ventenata abundance. One study found that the effects of integrated treatments differed with pretreatment ventenata cover, and that for plots with high pretreatment cover of ventenata, ventenata cover and biomass were least when herbicide was applied after prescribed fire [114]. Two studies found that ventenata abundance was similar on plots following integrated treatments and on untreated control plots [6,162]. Another study found ventenata abundance was higher on plots following integrated treatments than on untreated control plots, likely due to increased soil disturbance on treated plots that facilitated ventenata seedling emergence [65].

Near Troy, Idaho, a small-scale, short-term study that examined control of ventenata in Palouse prairie dominated by nonnative grasses (ventenata, orchardgrass, Japanese brome, meadow foxtail) and a native forb (tall annual willowherb) found that spring or fall prescribed fire followed by herbicide reduced ventenata abundance the following growing season. Treatments and combinations are shown in table 3. Treatment efficacy was evaluated in plots with high (>50%) and low (<25%) pretreatment ventenata cover. During the summer after treatments, plots with high pretreatment cover of ventenata that were treated with either spring or fall prescribed fire (fig. 9) followed by herbicide had less ventenata cover and biomass than untreated control plots. Mean cover and biomass was less in spring prescribed fire + herbicide plots than in spring prescribed fire-only plots, but mean cover and biomass was similar between fall prescribed fire + herbicide plots and fall prescribed fire-only plots. Plots with low pretreatment cover of ventenata that were treated with spring or fall prescribed fire and herbicide had similar ventenata cover and biomass to untreated controls, except that fall prescribed fire + herbicide plots had lower ventenata biomass than fall prescribed-only plots (table 3). Prescribed burning prior to herbicide application might have increased herbicide contact and effectiveness on some plots by burning off litter. However, the author stressed the importance of considering treatment effects on other nonnative species present before implementing an integrated control program for ventenata [114].

Table 3—Mean foliar cover and biomass of ventenata in summer 2013 after treatments occurring from fall 2012 to spring 2013 in Palouse prairie dominated by nonnative grasses with high and low pretreatment ventenata cover. Treatment results with the same letter in the same column are not significantly different from each other ($p < 0.05$). Treatment results that are different from those of control plots are bolded. Table modified from Mackey (2014) [114].

Treatment	Foliar cover (%)	Biomass (kg/ha)
High pretreatment ventenata cover (>50%)		
Control	45.30 d	83.90 c
Fall Rx fire	**19.70 abc**	**27.60 ab**
Spring Rx fire	35.30 cd	**40.10 b**
Fall sulfosulfuron	**23.00 abc**	**19.10 ab**
Fall Rx fire + fall sulfosulfuron	**10.20 a**	**6.50 a**
Spring Rx fire + fall sulfosulfuron	**12.80 ab**	**4.30 a**
Fall fertilizer	42.70 d	100.40 c
Fall fertilizer + fall sulfosulfuron	**21.80 abc**	**17.20 ab**
Sickle mow & remove vegetation	45.80 d	117.00 c
Sickle mow & remove vegetation + fall sulfosulfuron	**23.80 abc**	**5.70 a**
Rotary mow	50.30 d	106.80 c
Rotary mow + fall sulfosulfuron	28.00 bc	**11.20 ab**
Low pretreatment ventenata cover (<25%)		
Control	31.50 ce	29.10 abc
Fall Rx fire	17.80 abc	32.30 cde
Spring Rx fire	17.30 abc	32.80 abc
Fall sulfosulfuron	**2.50 ab**	3.00 a
Fall Rx fire + fall sulfosulfuron	**1.70 a**	1.80 a
Spring Rx fire + fall sulfosulfuron	**2.20 ab**	14.20 ab
Fall fertilizer	32.30 cde	**70.40 d**
Fall fertilizer + fall sulfosulfuron	**1.30 a**	8.20 ab
Sickle mow & remove vegetation	35.80 de	50.70 cd
Sickle mow & remove vegetation + fall sulfosulfuron	**9.20 ab**	4.40 a
Rotary mow	38.30 e	40.00 bcd
Rotary mow + fall sulfosulfuron	19.30 bcd	15.10 ab

Figure 9—Burn treatments in 5 m × 5 m plots in Palouse prairie dominated by nonnative grasses near Troy, Idaho. Photos used with permission from Timothy Prather, Invasive Plant Biology Lab, Department of Plant Sciences, College of Agricultural and Life Sciences, University of Idaho.

A longer-term study examined the combined effects of prescribed fire (fall of 2006 and 2016) and cattle grazing (annually since 2004) on ventenata abundance in Palouse prairie at the Zumwalt Prairie Preserve and found that it increased over time in all plots, which included plots that were grazed, burned, grazed + burned, and ungrazed + unburned controls. Overall, ventenata cover increased by 30% and frequency increased by 55% from 2008 to 2018. In 2018, ventenata cover, frequency, and density were similar among plots, but generally highest in unburned cattle-grazed areas [162].

In Mima mound prairie at Turnbull National Wildlife Refuge, ventenata density in three basalt intermound areas was not different between treated and untreated control plots less than 1 year after prescribed fires (18 October and 8 November), herbicide application (27-28 November, timed to coincide with fall germination), and/or simulated trampling (3 December). Ventenata density decreased by 60% in all treated and control plots, likely due to below-average precipitation after treatments. Native species richness also decreased in all treated and control plots, but native plant cover increased, especially on plots with herbicide treatments. Despite a lack of treatment effects on ventenata density, the researcher recommended using fall prescribed fire to remove the extensive ventenata litter layer (timed when ventenata is growing and native species are dormant) followed by herbicide application to kill ventenata and increase native species cover, with the caveats that 1) this recommendation was based on less than 1 year of posttreatment observations, and 2) prescribed fires should not be frequent or severe and are only appropriate in areas where native species are fire-adapted [6].

Management practices that disturb soil may increase ventenata abundance. In Palouse prairie near Ritzville, Washington, ventenata density was higher in plots with seedbed preparation treatments followed by seeding of perennial grasses than in untreated, unseeded control plots (table 4). Prescribed fire removed the dense litter layer that was present on undisturbed seedbeds, while disking incorporated litter into the soil. Less than 1 year after treatments, annual grass seedling density, which consisted mostly of ventenata, was greater on all treated plots compared to untreated control plots, with the exception of burned + herbicide and fall-disked plots, where ventenata density was similar to control plots [65].

Table 4—Mean seedling density (seedlings/m^2) of cheatgrass, other annual grasses, and annual forbs in Palouse prairie in May 1983, after varied seedbed preparation treatments and seeding of bluebunch wheatgrass and nonnative desert wheatgrass in 1981 and 1982. Precipitation was above average from October 1982 to June 1984. Different lower-case letters within a row indicate a significant difference between treated and control plots ($p < 0.05$). Table modified from Haferkamp et al. (1987) [65].

Species	Control	Prescribed fire		Summer prescribed fire-spring herbicide		Spring herbicide			Disking	
		Summer	Fall	A[b]	B[b]	A[b]	B[b]	C[b]	Spring	Fall
Cheatgrass	240a	90b	205a	37b	36b	172a	255a	321a	255a	202a
Other annual grasses[a]	166a	602b	296a	527b	509b	547b	948b	1224b	611b	271a
Annual forbs	879a	603b	464b	403b	583b	959a	787a	611b	757a	441b

[a]Other annual grasses consisted mostly of ventenata.
[b]Herbicides used were A) glyphosate, B) paraquat, and C) atrazine.

Sagebrush Steppe

Wildfires may provide opportunities for integrated management of ventenata. For example, in sagebrush steppe communities previously invaded by cheatgrass in the Owyhee Mountains in southwestern Idaho and southeastern Oregon, plots sprayed with herbicides within 2 years of the 2015 Soda Fire had less ventenata than unsprayed plots. Probability of ventenata occurrence increased over time since fire and had increased by more than 30% overall by postfire year 5. In contrast, the probability of ventenata occurrence decreased by 32% on plots that were sprayed [7] (see Plant Response to Fire: Sagebrush Steppe).

NONFIRE MANAGEMENT CONSIDERATIONS

Federal Status

None

Other Status

As of 2022, ventenata was classified as a noxious weed in Montana, Oregon, Utah, Washington, and Wyoming [125,146,187,194,201]. It is on the Colorado State Noxious Weed Watch List [40].

IMPORTANCE TO WILDLIFE AND LIVESTOCK

Ventenata has limited use as ungulate forage and has little to no value for wildlife. Dense ventenata degrades wildlife habitat by replacing native species [25,88,114]. For example, ventenata has been associated with a decline in nesting success of insect-eating birds due to reduced plant species diversity, altered plant structure, and insect abundance [114].

Palatability and Nutritional Value

Ventenata has relatively low palatability to cattle, domestic sheep, and domestic goats [107,108,123], which is attributed to high silica content [147,162] and resultant wiry growth [107]. Pavek et al. (2011) reported "high" silica content of ≈2.7% at the time of seedhead production [147], but Ridder et al. (2022) remarked that this was within the range of common rangeland grasses [162]. Spackman (2019) reported that acid insoluble ash concentration, an indicator of silica content, was high in ventenata (5.9% to 7.0%) but higher in medusahead (7.5% to 9.2%) collected in Cache County, Utah [172]. Feeding trials of pelleted and unpelleted ventenata indicated that its wiry growth reduces its palatability to cattle rather than its silica content [107,123], although pelleting ventenata did not improve its palatability to domestic goats or domestic sheep [108]. Majeski (2020) commented that the displacement of cheatgrass by ventenata in the Snake River Canyon grasslands of Idaho is "particularly alarming" because ventenata is less palatable to livestock than cheatgrass, which at least "provides some grazing options" [117].

Ventenata "could serve as an early forage" for livestock [70]. It is most suitable for grazing in its early growth stages (i.e., in mid-spring before panicles emerge) [51,126,168,193], when silica content is presumably lowest and crude protein content similar to that of associated perennial grasses [70,108,147]. Even then, ungulates may not select it if other herbaceous forage is available. Its comparatively slow growth rate and short stature in early spring probably reduce grazing pressure on ventenata compared to associated grass species [155,190].

Cover Value

Ventenata provides cover for small mammals and birds until it dries [114].

OTHER USES

Besides limited value as spring forage for livestock, ventenata has no known economic, medicinal, or ecological value [158,168]. It does not provide erosion protection because its shallow roots do not hold soil as well as the roots of native perennial grasses [17].

IMPACTS

Impacts on Native Plant Communities

Ventenata's range expanded rapidly in the Pacific Northwest during the early 21st century. It is particularly invasive in Palouse prairie and sagebrush steppe [193]. Ventenata is also invasive in open, dry ponderosa pine, dry Rocky Mountain Douglas-fir, and dry mixed-conifer forests [9,10,66,100,133]. Ventenata invasion may increase fuel loads and fuel continuity, which could result in increased fire frequency and fire spread in some invaded communities, such as scablands [67,181], Palouse prairie [96] and sagebrush steppe [62,100] (see Fuel and Fire Characteristics and Fire Regimes).

Palouse prairie is a critically endangered ecosystem [139,166]. Agriculture and nonnative annual grass invasion are the primary causes of Palouse prairie loss and degradation [47,112]. Only 1% to 6% of historical Palouse prairie remains, and this occurs mostly on the edges of streams and croplands, on steep slopes and ridges [21,47], and on other untillable sites [53]. Ventenata is considered one of the primary weeds constraining restoration of remnant Palouse prairie in the Inland Northwest [192].

Several impacts to native plant community composition and structure have been associated with ventenata invasion. Ventenata invasion can reduce native perennial grass and forb cover [11,196], diversity [25,90,140,168,180], and richness [90,91,196]; reduce bare ground cover [11]; and alter community structure and ecosystem function [25,140]. For example, among plots with no, low (<12.5%), and high ventenata cover (>12.5%) in Palouse prairie and canyon grassland in northern Idaho and eastern Washington, native plant species richness and diversity was lowest in plots with high ventenata cover [90]. In sagebrush steppe in eastern Oregon and southwestern Idaho, native plant community richness and diversity was also lowest in plots with high (>12.5%) ventenata cover. Medusahead and annual forbs that occur in disturbed, moist sites were more frequent in plots with ventenata than in plots without [91].

Ventenata invasion combined with fire could worsen impacts on native plant species richness and diversity [180]. In the Blue Mountains ecoregion, species diversity and richness decreased when ventenata cover increased in plots burned 1 to 4 years prior to sampling. Species diversity also decreased when ventenata cover increased in unburned plots, although not as much, and species richness was not strongly related to ventenata cover in unburned plots. Cover of annual forbs, annual grasses, nonnative species, and shrubs were negatively associated with ventenata cover in burned plots, while perennial forbs were negatively associated with ventenata in both burned and unburned plots. The researchers suggested that ventenata may be infilling gaps rather than interfering with resident species in unburned areas. In burned areas, ventenata may be competitively excluding native species, perhaps because it can more efficiently allocate postfire resources [180]. In Mima mound prairie at Turnbull National Wildlife Refuge, nonnative plant species richness was significantly greater on plots burned with prescribed fire than on plots with gopher disturbance, while richness of native plant species was significantly lower [41,42]. The researchers concluded that prescribed fire should be used with caution in areas with nonnative invasive annual grasses because interactive effects of prescribed fire and other disturbances are likely to result in increased abundance of nonnative annual grasses at the expense of native herbaceous species [41].

In Idaho, ventenata is invasive in habitats of several federally listed rare plants and may interfere with their reproduction and persistence: Idaho pepperweed, Palouse goldenweed, and Spalding's catchfly ([75], review by [130]). Ventenata is considered one of the most invasive herbaceous plants in Spalding's catchfly Palouse prairie habitats [75].

Impacts on Agriculture and Agriculture-Wildland Mosaics

Ventenata invasions have caused economic losses in the Northwest. Ventenata contamination lowers the value of hay [192]. Timothy, Kentucky bluegrass, alfalfa, and other crop fields are especially prone to ventenata invasion [140,193], reducing yields by as much as 50% [193] to 75% within a few years [190].

Ventenata can host barley cereal yellow dwarf virus (BCYDV), which can infect crops such as common barely and common wheat and potentially infect native bunchgrasses [78]. BCYDV is vectored by aphids that prefer feeding on annual rather than perennial grasses [119]. Ventenata and other nonnative annual grasses may attract BCYDV vectors and amplify BCYDV infection rates of perennial grasses [78,119] in Palouse prairies [78] and other communities in the Pacific Northwest. In Palouse prairie remnants and adjacent nonnative perennial grasslands in southeastern Washington and adjacent northern Idaho, 41% of ventenata plants sampled were found to be infected with BCYDV and none displayed symptoms [79].

Impacts on Wildlife and Livestock

Ventenata invasions can reduce habitat and forage for wildlife [25,114,192] and forage for livestock [70,91,193]. For more information, see Importance to Wildlife and Livestock.

Impacts on Soils

Because ventenata has shallower roots than perennial grasses, invaded sites are prone to more erosion than uninvaded sites when perennial grass cover is reduced [25,114,168,193].

INVASION SUCCESS

Mechanisms of ventenata invasion success were not well studied as of 2022. Ventenata, medusahead, and cheatgrass are nonnative, invasive winter annual grasses that often occur together (e.g., [90,91,102,138]). In Palouse prairie and sagebrush steppe, ventenata can displace these grasses [14,28,88,91,137,190,199] (see Succession). In other areas, ventenata has a unique niche and invades habitats where other nonnative invasive annual grasses do not occur [133,180].

Although ventenata is known to displace cheatgrass and medusahead on some sites (see Succession) it may be more competitive for resources with native perennial bluebunch wheatgrass than with either of these annual grasses. In a greenhouse experiment, cheatgrass, medusahead, and bluebunch wheatgrass were grown in pots separately and with ventenata. After 38 days, bluebunch wheatgrass seedlings grown with ventenata seedlings had 20% less shoot biomass than when grown alone, while cheatgrass and medusahead seedlings grown with ventenata had similar biomass as when grown alone. Ventenata emerged last and bluebunch wheatgrass emerged second to last; thus, ventenata may have had more overlap in timing of resource use and growth with bluebunch wheatgrass than with either cheatgrass or medusahead [124].

As a winter annual with shallow roots, ventenata uses shallow soil water in early spring, and it may outcompete some native annual herbaceous plants when this resource is limited early in the growing season [9]. However, because ventenata does not have an extensive root system, it may be less competitive for soil moisture than other nonnative annual grasses. A growth chamber experiment found that among ventenata, cheatgrass, and medusahead, ventenata gained the least root biomass with pulses of watering designed to simulate pulses of precipitation, while medusahead gained the most root biomass. Shoot biomass gain was similar among the three grasses and did not differ with increasing clay content of soil. Medusahead's greater biomass allocation to roots and greater responsiveness of root growth to differing precipitation regimes may favor its ecological success over ventenata and cheatgrass in areas with large-infrequent precipitation events [14].

Ventenata is a poor competitor for available soil nitrogen. In a garden study with nitrogen-limited soils, ventenata produced the least leaf and total biomass, the shortest roots, and the fewest tillers among five associated grass species (bluebunch wheatgrass, squirreltail, cheatgrass, crested wheatgrass, and medusahead). Unlike the more competitive grasses, which had greater nitrogen capture and growth with increased soil nitrogen availability, ventenata took up soil nitrogen at a steady rate regardless of the amount of nitrogen applied to the soil [86].

Soil fungi may offer a competitive advantage to ventenata over cheatgrass and bluebunch wheatgrass. While collecting ventenata and cheatgrass from a Palouse prairie on Paradise Ridge, northern Idaho, Griffith [64] observed that ventenata plants infected with *Fusarium* spp. fungi were taller than uninfected plants, while cheatgrass plants infected with *Fusarium* spp. were shorter than uninfected plants. As a follow-up experiment, *Fusarium* spp. were isolated from infected ventenata and cheatgrass and cultured in the laboratory. In a greenhouse, ventenata, cheatgrass, and bluebunch wheatgrass seeds were planted in either soil inoculated with the fungi or in uninoculated soil. *Fusarium* spp. inoculation increased seedling emergence and aboveground biomass of ventenata seedlings compared to uninoculated seedlings but reduced seedling emergence and aboveground biomass of cheatgrass and bluebunch wheatgrass seedlings compared to uninfected seedlings. Griffith (2015) suggested that *Fusarium* spp. have a symbiotic relationship with ventenata but is pathogenic to cheatgrass and bluebunch wheatgrass, and that these relationships may contribute to ventenata's ability to establish and spread in cheatgrass monocultures and remnant Palouse prairies [64].

Ventenata's thick litter can prevent or inhibit establishment of native perennial grasses [88], while possibly benefitting its own seedling emergence and survival [88] (see Seedling Emergence, Establishment, and Suvival).

PREVENTION

The most effective means to prevent ventenata establishment and spread is to maintain healthy native plant communities [126,168,193] (see Revegetation) and limit soil disturbance and vegetation removal [8,23,63,186] (see Preventing Postfire Establishment and Spread). Maintaining the integrity of native plant communities and mitigating the factors enhancing ecosystem invasibility are likely to be more effective than solely controlling the invader [77]. The loss of perennial bunchgrasses, removal of shrubs and trees, and soil disturbance increase the likelihood of annual grass invasion and eventual dominance. For example, caution and monitoring are warranted when removing western juniper from sagebrush steppe, because nonnative invasive grasses, including ventenata, are likely to establish after such disturbances [97]. Maestas et al. (2022) stated that identifying intact rangelands and protecting them from annual grass invasion is a top priority for rangeland management. Minimizing vulnerability of rangelands to annual grass conversion includes 1) reducing exposure to annual grass seed sources, 2) improving resilience and resistance by promoting perennial plants, and 3) building capacity of communities and partnerships to adapt to changing conditions and respond to the problem with appropriate actions in a timely manner [115].

As an annual, ventenata establishes and spreads from seeds, so preventing seed dispersal to uninvaded sites is critical [117]. Cleaning equipment before leaving ventenata-invaded areas [29,168,193], seeding bare areas with weed-free seeds [29,167,168], and careful rotation of livestock [29,167] can help prevent ventenata establishment and spread and promote healthy native plant communities.

Weed prevention and control can be incorporated into many types of management plans, including those for fire management; logging and site preparation; grazing allotments; recreation management;

road building and maintenance; and research projects [186]. See the Guide to Noxious Weed Prevention Practices [186] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

CONTROL

In all cases where invasive species are targeted for control, the potential for other invasive species to fill their void must be considered no matter what method is employed [26]. Control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders [113]. In addition, effects on nontarget plants are important considerations in any control program [103].

Rapid detection and eradication of new invasions is important to contain spread of ventenata and other nonnative invasive plants [132,169]. Adhikari et al. (2021) stated that locating new populations along road corridors is vital as these populations can act as source populations for invasions into adjacent land, particularly grasslands and agricultural lands [2]. Jones et al. (2018) concluded that in sagebrush steppe ecosystems, ventenata management efforts should: 1) focus initial monitoring efforts around areas where medusahead has previously established or has the potential to be a problem due to the positive association between medusahead and ventenata distribution in this ecosystem; and 2) focus control and restoration efforts on moist microsites, as these may act as source populations for ventenata spread [91].

Control programs are necessary when ventenata populations are well established [135]. Once established, a multi-step, multi-year approach is often needed to control ventenata and other invasive annual grasses [103]. Because ventenata is an annual with a short-term seed bank, control programs focused on preventing establishment and stopping or reducing seed production can be most successful [17,120]. Ventenata seeds are thought to persist in the soil for <4 years, so 3 or 4 years of control, followed by monitoring and follow-up control, may eliminate or greatly reduce its establishment and spread [155,167]. However, information on the long-term effectiveness of control strategies is lacking.

Fire

See the Fire Management Considerations section of this Species Review.

Physical and Mechanical Control

Manual Removal

Hand-pulling may control new, small ventenata populations. Because ventenata has shallow roots, it pulls easily when soil is moist [51,168,193].

Mowing

Mowing ventenata multiple times throughout the growing season may prevent it from producing seeds (Gribble 2008, personal communication cited in [168]). Mowing once is unlikely to reduce ventenata abundance because ventenata usually sprouts when cut before flowering and can produce a flush of seedheads [168]. For example, a small-scale study near Troy, Idaho, found that plots mowed once in August had similar ventenata cover and biomass the following summer compared with unmowed control plots (table 3) [114]. Scheinost et al. (2008) suggest that keeping ventenata <5 cm tall until soil dries and growth stops [167] may prevent seed production [166,168].

Ventenata stems are tough and require sharp equipment and slow mow speeds [193]. Mowing when seeds are heading is difficult because the culms often bend over or get tangled in blades [168].

Mowing prior to herbicide application may be more effective at controlling ventenata than mowing alone, especially in dense stands; however, it may not be more effective that herbicide alone (table 3) [114].

Biological Control

Biological controls were not available for ventenata as of 2022 [51,168,193], and because ventenata is in the same taxonomic tribe as oats (Aveaneae) [29], use of biological control agents would likely be limited due to potential adverse impacts on oat crops. A 2017 workshop concluded that the feasibility of biological control is moderate for ventenata, but the likelihood of success is low. Two nonspecific pathogens are listed as natural enemies of invasive winter annuals in North America, *Septoria ventenatae* and *Tilletia fusca* [158]. Natural enemies in its native range that limit ventenata abundance may have potential as biological control agents in North America. Alomran et al. (2019) found that fungi and other pathogens (e.g., rusts, powdery mildew, and choke) were absent on ventenata plants surveyed in the Pacific Northwest, but present on plants in its native range [5].

Livestock Grazing

Given ventenata's unpalatability, livestock grazing is not likely to control it [193]. Studies of grazing effects on ventenata are inconsistent, although most studies show increased ventenata abundance with grazing in grassland and steppe communities [87,147,162], and one study in dry mixed-conifer forests at the Starkey Experimental Forest and Range, Oregon, found no effect of grazing on ventenata abundance. This study found that cover of annual grasses, which included ventenata, cheatgrass, and nonnative dense silkybent, was similar among cattle-grazed, elk-grazed, and ungrazed plots after 7 years [148].

In grassland and steppe, ventenata abundance can increase in areas that are heavily grazed by elk [87] and in areas that are grazed by both cattle and elk [162] relative to ungrazed areas. At the Zumwalt Prairie Preserve, ventenata standing crop was about 14 g/m greater and cover about 4% greater on grazed plots than plots where grazing was excluded for 14 years. Plots were grazed primarily by cattle but also by elk. In a related study in the same location, ventenata cover and frequency were generally higher in grazed than ungrazed plots during three sampling periods (2008, 2016, and 2018); however, differences between plots were not statistically significant in any period, and ventenata abundance increased over time in both grazed and ungrazed plots [162]. See Integrated Management with Fire for more details from this study. Results of studies that examine grazing effects on ventenata may differ due to kind of grazing (i.e., cattle versus elk), length and intensity of grazing, or season of grazing. Ventenata's late phenological development compared with associated species is likely to contribute to its increase with spring grazing when it is shorter and less accessible to grazers than associated grasses [155,162,190] (see Palatability and Nutritional Value).

Grazing management that maintains perennial bunchgrass abundance can indirectly provide some ventenata control [51]. Deferring grazing until late summer or fall, after perennial grasses shatter their seeds, promotes bunchgrass health and recovery from grazing [16,27,189].

Chemical Control

Herbicides may be effective in gaining initial control of a population of nonnative invasive plants, but they are rarely a complete or long-term solution to weed management [34]. They may control ventenata best when combined with follow-up planting or seeding of competitive herbaceous species [114,193]. For large populations, herbicides are most effective when incorporated into long-term management plans that include replacement of weeds with desirable species (see Revegetation), careful land use management, and prevention of new invasions. See the Weed Control Methods Handbook [182] for considerations on the use of herbicides in wildlands and detailed information on specific chemicals.

Herbicides have helped reduce ventenata cover in the short term (e.g., [20,32,46,70,72,106,164,170,174,191]), and while herbicides may help control ventenata in some plant communities (e.g., [39]), they may also reduce cover, diversity, and richness of native plants, depending on the type, rate, and timing of herbicide applied and site characteristics such as climate and weather (e.g., [32,72,106,164]). Regardless of the type of herbicide used, follow-up treatments are needed for lasting control [46]. However, there is concern that ventenata may develop herbicide resistance with long-term herbicide use; ventenata is reported to be resistant to some herbicides [118].

Herbicides that kill ventenata seedlings in late fall before they have a chance to establish and reproduce may be most effective for depleting ventenata's soil seed bank [193]. See these publications for timing, application rates, and other details of herbicide use to control ventenata: [29,51,168,188,191,198].

Combining fertilizer and herbicide application may not improve ventenata control or increase perennial grass cover compared with using herbicide alone [114]. In Palouse prairie dominated by nonnative grasses in Troy, Idaho, ventenata cover was similar between plots treated with herbicide and plots treated with herbicide + fertilizer, and cover in both these plots was lower than in untreated control plots (table 3). Nonnative perennial forage grass cover was higher in herbicide-only than controls plots, but herbicide + fertilizer plots had similar cover as control plots [114]. In nonnative perennial grasslands in Moscow and Grangeville, Idaho, herbicide and herbicide + fertilizer plots had similar ventenata cover and both plots had lower ventenata cover than that in untreated control plots within the first growing season. Nonnative perennial grass cover tended to be higher in herbicide and herbicide + fertilizer plots than in control plots, although results depended on plant community [191].

Reducing nutrients available to ventenata by applying a carbon source may also help control it. Low rates of sucrose were applied in a Pacific Northwest semiarid grassland in early spring to stimulate microbial growth and reduce nutrient availability to ventenata. Sucrose application reduced ventenata cover, seed production, and seed mass with no corresponding impact on perennial or other annual plants, except at the highest application rate. The researchers suggested that this method has the potential to not only target invasive winter annual grasses, but any plants that are active earlier or later than the rest of the plant community [109].

Integrated Management

Best long-term control of ventenata is likely to be accomplished with a combination of control and revegetation methods. Examples of integrated management with short-term success in reducing ventenata abundance include combinations of prescribed fire, mowing, and herbicide followed by seeding [28,29,35,114]. Some examples of combined approaches are presented within the preceding sections and in Fire Management Considerations.

REVEGETATION

Establishing and/or maintaining healthy and competitive vegetation is likely to reduce site invasibility. Revegetation is often necessary after control treatments because removing one species leaves open niches for reinvasion or for new invaders to establish [103]. Several studies suggest that ventenata abundance is positively associated with annual grass and annual forb abundance [91,180] and negatively associated with perennial grass and perennial forb abundance [7,91,180], suggesting that revegetating with perennials may reduce site invasibility [117]. For example, in the Blue Mountains ecoregion, areas with highest risk of ventenata invasion were those dominated by annual grasses and annual forbs, and limited evidence suggested that perennial grasses conferred some resistance to ventenata invasion. There was a negative relationship between ventenata cover and perennial forb cover in both burned and unburned plots, suggesting that ventenata may preferentially invade areas with relatively low cover of established perennial forbs [180]. At five rangeland sites in Montana, ventenata was positively associated with nonnative perennial grasses and negatively associated with native perennial grasses, suggesting that revegetating with native perennial grasses could prevent or limit ventenata invasion [117]. Some researchers have hypothesized that ventenata invasion may lead to the establish of a grass/fire cycle in some communities, as has been documented in sagebrush ecosystems invaded by cheatgrass (see Fuel and Fire Characteristics). Maintaining and restoring perennial bunchgrasses in fire-dominated annual-grass landscapes requires breaking (lengthening) the fire cycle [149].

Planting competitive herbaceous plants after other control treatments may reduce ventenata cover. Native herbaceous plants that have been planted after ventenata control in Palouse prairie include bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass, common yarrow, and Eaton penstemon [142]. Seeding species with a variety of life history traits, especially those that are functionally similar to invaders, increases the likelihood of successful establishment of desirable species and suppression of nonnative grass by capturing more resources (e.g., light, water, soil nutrients) and space [7,98,103,178]. Tortorelli et al. (2022) found that resident biomass was one of the strongest drivers of plant community resistance to ventenata invasion and concluded that resistance may be strongest in productive sites with high resident biomass, high niche overlap with ventenata, and fewer openings (e.g., ephemeral wet meadows) than in plant communities with low biomass, low niche overlap, and more openings (e.g., scabland flats and low sagebrush steppe). They noted, however, that ventenata “successfully invaded and became abundant” in all three plant communities along a productivity gradient [178].

MANAGEMENT UNDER A CHANGING CLIMATE

In the western United States, high temperature extremes are projected to become more frequent and to last for longer periods, while low temperature extremes are projected to become less frequent; and atmospheric carbon dioxide is expected to double across all ecosystems, even in the most conservative climate estimates [84]. Models indicate that ventenata populations are likely to increase in extent with these predicted changes [2,4,55,99]. For example, climate models based on 314 reported occurrences of ventenata in the United States [4] predicted that by about 2050, ventenata is likely to spread throughout the western and eastern United States (fig. 10) [55].

By mid-century, average annual temperature and precipitation are projected to increase in southwestern Montana (up to 2.5 °C and 25 mm, respectively, depending on the emission scenario), but summers are predicted to be drier [197]. In Gallatin County, Montana, bioclimatic niche models based on 467 ventenata presence records along surveyed roads predicted that by 2040 suitable habitat for ventenata is likely to increase with these predicted climate changes, with greater increases under the scenario with the greatest increase in temperature and precipitation. Ventenata was projected to spread in all land cover types (forest, shrubland, grasslands, agricultural lands, and developed lands), with the greatest increases on agricultural lands and grasslands, and the least increase in forests [2].

Harvey et al. (2020) examined differences in ventenata and cheatgrass seedling growth when grown alone or together under 2018 temperatures (4 °C nighttime/23 °C daytime) and carbon dioxide levels (400 ppm) compared to predicted future (2100) temperatures (10.6 °C/29.6 °C) and carbon dioxide levels (800 ppm). Cheatgrass was larger than ventenata across climate and competition treatments, and both species were smaller in the future climate treatment. Ventenata allocated more growth to its roots than cheatgrass under both climate treatments, suggesting that ventenata may have a competitive advantage over cheatgrass for soil resources [71].

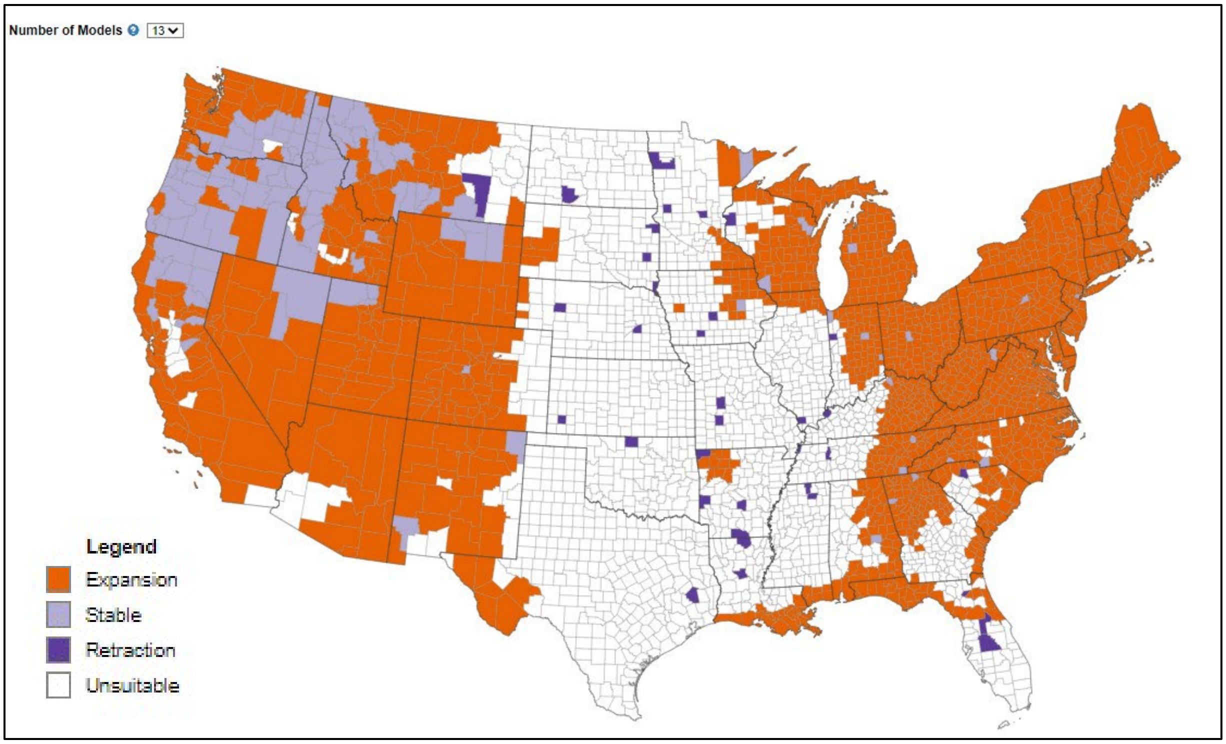

Figure 10—County-level distribution of the modeled future range (about 2050) of ventenata in the United States, based on climate change models from Allen et al. (2016) [4]. Map courtesy of EDDMapS [55] [6 April 2022].

APPENDIX

Table A1—Common and scientific names of plant species mentioned in this Species Review. Links go to other FEIS Species Reviews. Nonnative species are indicated with an asterisk*.

Common name	Scientific name
Trees	
fir	Abies *spp.*
grand fir	*Abies grandis*
juniper	*Juniper* spp.
oak	*Quercus* spp.
Oregon white oak	*Quercus garryana*

pine	*Pinus* spp.
ponderosa pine	*Pinus ponderosa* var. *ponderosa*
Rocky Mountain Douglas-fir	*Pseudotsuga menziesii* var. *glauca*
Rocky Mountain lodgepole pine	*Pinus contorta* var. *latifolia*
spruce	*Picea* spp.
western juniper	*Juniperus occidentalis*
white fir	*Abies concolor*
Shrubs	
antelope bitterbrush	*Purshia tridentata*
big sagebrush	*Artemisia tridentata*
common snowberry	*Symphoricarpos albus*
low sagebrush	*Artemisia arbuscula*
mountain big sagebrush	*Artemisia tridentata* subsp. *vaseyana*
Pacific poison-oak	*Toxicodendron diversilobum*
sagebrush	*Artemisia* spp.
scabland sagebrush	*Artemisia rigida*
silver sagebrush	*Artemisia cana*
snowberry	*Symphoricarpos* spp.
Wood's rose	*Rosa woodsii*
Wyoming big sagebrush	*Artemisia tridentata* subsp. *wyomingensis*
Forbs	
alfalfa*	*Medicago sativa*
Idaho pepperweed	*Lepidium papilliferum*
largehead clover	*Trifolium macrocephalum*
Palouse goldenweed	*Pyrrocoma scaberula*
Spalding's catchfly	*Silene spaldingii*
tall annual willowherb	*Epilobium brachycarpum*
Graminoids	
bluebunch wheatgrass	*Pseudoroegneria spicata*
blue wildrye	*Elymus glaucus*
bromes	*Bromus* spp.
California oatgrass	*Danthonia californica*
cheatgrass*	*Bromus tectorum*
common barley*	*Hordeum vulgare*
common wheat*	*Triticum aestivum*
crested wheatgrass*	*Agropyron cristatum*
dense silkybent*	*Apera interrupta*
desert wheatgrass*	*Agropyron desertorum*
Idaho fescue	*Festuca idahoensis*
Japanese brome*	*Bromus japonicus*
Kentucky bluegrass*	*Poa pratensis*
oat*	*Avena* spp.
onespike oatgrass	*Danthonia unispicata*
orchardgrass*	*Dactylis glomerata*

meadow foxtail*	*Alopecurus pratensis*
medusahead*	*Taeniatherum caput-medusae*
purple threeawn	*Aristida purpurea*
red fescue*	*Festuca rubra*
Roemer's fescue	*Festuca idahoensis* subsp. *roemeri*
Sandberg bluegrass	*Poa secunda*
sand dropseed	*Sporobolus cryptandrus*
squirreltail	*Elymus elymoides*
timothy*	*Phleum pratense*
ventenata*	*Ventenata dubia*

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