SPECIES: Acroptilon repens

INTRODUCTORY

SPECIES: Acroptilon repens

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FEIS ABBREVIATION:
ACRREP

SYNONYMS:
Centaurea repens L. [20,33,43,81]

NRCS PLANT CODE [77]:
ACRE3

COMMON NAMES:
Russian knapweed
hardheads
creeping knapweed

TAXONOMY:
The currently accepted scientific name of Russian knapweed is *Acroptilon repens* (L.) DC. (Asteraceae) [37,39,40,84].

LIFE FORM:

Forb

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
At the time of this writing (2001), Russian knapweed is classified as a noxious, restricted or prohibited weed or weed seed in 25 states in the United States and 4 Canadian provinces [78]. See the Invaders or Plants databases for more information.

DISTRIBUTION AND OCCURRENCE

SPECIES: Acroptilon repens

GENERAL DISTRIBUTION:
Russian knapweed is native to Mongolia, western Turkestan, Iran, Turkish Armenia, and Asia Minor [45], and is found in cultivated fields and dry pastures of the southern Ukraine, southeastern Russia, and western Kazakhstan. It is considered a serious weed of dryland crops in the southern parts of the former Soviet Republics ([83], and sources therein). Russian knapweed was initially introduced to North America in the early 1900's, primarily as a contaminant of Turkestan alfalfa (*Medicago sativa*) seed (Groh 1940, as cited by [83]) and possibly sugarbeet (*Beta vulgaris*) seed (Robbins and others 1951, as cited by [45]). Rogers [61] suggests that Russian knapweed is likely to have established wherever Turkestan alfalfa has been planted. Its spread from these locations is linked to the distribution of knapweed-infested hay [61,83].

Russian knapweed is widespread in the U.S. and especially common in the semiarid portions of the western states and adjacent Canada. Maddox and others [45] reported infestations in South Dakota, Minnesota, and Virginia in 1985, and current distribution maps indicate its occurrence in several midwestern and Great Plains states [40,77]. The Plants database provides a distribution map of Russian knapweed in the United States.

The following table reflects estimates of Russian knapweed acreage as reported by surveyed states or provinces in 1988 and again in 2000 (from [25]):

State/Province	1988 Acreage	2000 Acreage
Arizona	not reported	5,500
California	not reported	150
Colorado	50,000	168,000
Idaho	890,000	425,000
Kansas	not reported	5
Montana	47,893	64,456

Nevada	not reported	75,000
New Mexico	not reported	15,000
North Dakota	250	436
Oregon	15,000	85,000
South Dakota	3,045	2,717
Utah	150,000	60,000
Washington	8,050	500,000
Wyoming	200,000	160,000
Alberta	20	scattered
British Columbia	not reported	450
Total		1,561,714

Although inventories are more common and more accurate in the year 2000 than in 1988, 50% of these states reported only 50% accuracy, while 31% reported 51 to 75% accuracy, and 2 states reported 75 to 100% accuracy in the 2000 survey [25].

The following biogeographic classification systems are presented as a guide to demonstrate where Russian knapweed might be found based on reported occurrence and biological tolerance to factors that are likely to limit its distribution. Precise distribution information is limited, especially in the southwestern, central, midwestern, and eastern states. Therefore, these lists are speculative and not exhaustive.

ECOSYSTEMS [31]:
FRES29 Sagebrush
FRES30 Desert shrub
FRES32 Texas savanna
FRES33 Southwestern shrubsteppe
FRES35 Pinyon-juniper
FRES38 Plains grasslands
FRES39 Prairie
FRES40 Desert grasslands

STATES:

AZ	AR	CA	CO	ID	IL
IN	IA	KS	KY	MI	MN
MO	MT	NE	NV	NM	ND
OH	OK	OR	SD	TX	UT
VA	WA	WI	WY		

AB	BC	MB	ON	SK

BLM PHYSIOGRAPHIC REGIONS [11]:
3 Southern Pacific Border
4 Sierra Mountains

5 Columbia Plateau
6 Upper Basin and Range
7 Lower Basin and Range
8 Northern Rocky Mountains
9 Middle Rocky Mountains
10 Wyoming Basin
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains
15 Black Hills Uplift
16 Upper Missouri Basin and Broken Lands

KUCHLER [42] PLANT ASSOCIATIONS:
K023 Juniper-pinyon woodland
K024 Juniper steppe woodland
K038 Great Basin sagebrush
K040 Saltbush-greasewood
K041 Creosote bush
K050 Fescue-wheatgrass
K051 Wheatgrass-bluegrass
K055 Sagebrush steppe
K056 Wheatgrass-needlegrass shrubsteppe
K058 Grama-tobosa shrubsteppe
K059 Trans-Pecos shrub savanna
K063 Foothills prairie
K064 Grama-needlegrass-wheatgrass

SAF COVER TYPES [27]:
220 Rocky Mountain juniper
235 Cottonwood-willow
238 Western juniper
239 Pinyon-juniper

SRM (RANGELAND) COVER TYPES [70]:
101 Bluebunch wheatgrass
102 Idaho fescue
107 Western juniper/big sagebrush/bluebunch wheatgrass
211 Creosote bush scrub
235 Cottonwood-willow
301 Bluebunch wheatgrass-blue grama
302 Bluebunch wheatgrass-Sandberg bluegrass
303 Bluebunch wheatgrass-western wheatgrass
304 Idaho fescue-bluebunch wheatgrass
305 Idaho fescue-Richardson needlegrass
306 Idaho fescue-slender wheatgrass
309 Idaho fescue-western wheatgrass
310 Needle-and-thread-blue grama
311 Rough fescue-bluebunch wheatgrass
312 Rough fescue-Idaho fescue
314 Big sagebrush-bluebunch wheatgrass
315 Big sagebrush-Idaho fescue
316 Big sagebrush-rough fescue

317 Bitterbrush-bluebunch wheatgrass
318 Bitterbrush-Idaho fescue
319 Bitterbrush-rough fescue
320 Black sagebrush-bluebunch wheatgrass
321 Black sagebrush-Idaho fescue
322 Curlleaf mountain-mahogany-bluebunch wheatgrass
323 Shrubby cinquefoil-rough fescue
324 Threetip sagebrush-Idaho fescue
401 Basin big sagebrush
402 Mountain big sagebrush
403 Wyoming big sagebrush
404 Threetip sagebrush
405 Black sagebrush
406 Low sagebrush
407 Stiff sagebrush
408 Other sagebrush types
412 Juniper-pinyon woodland
414 Salt desert shrub
415 Curlleaf mountain-mahogany
416 True mountain-mahogany
421 Chokecherry-serviceberry-rose
422 Riparian
501 Saltbush-greasewood
504 Juniper-pinyon pine woodland
609 Wheatgrass-grama
610 Wheatgrass
611 Blue grama-buffalo grass
612 Sagebrush-grass
613 Fescue grassland
614 Crested wheatgrass
615 Wheatgrass-saltgrass-grama

HABITAT TYPES AND PLANT COMMUNITIES:
Russian knapweed invades many disturbed western grassland and shrubland communities as well as riparian woodlands, such as the Fremont cottonwood (*Populus fremontii*)/skunkbush sumac (*Rhus trilobata*) community [17].

Pacific Northwest:
In eastern Washington, the most common associate of Russian knapweed is basin wildrye (*Leymus cinereus*) [75]. In this area, Russian knapweed occurs in big sagebrush (*Artemisia tridentata*)/bluebunch wheatgrass (*Pseudoroegneria spicata*), black greasewood (*Sarcobatus vermiculatus*)/saltgrass (*Distichlis spicata*) and basin wildrye/saltgrass habitat types [59]. Russian knapweed may also be found in the big sagebrush/basin wildrye habitat type in Oregon [56].

In Idaho, Russian knapweed may be found with bluebunch wheatgrass, Idaho fescue (*Festuca idahoensis*), snowberry (*Symphoricarpos* spp.), and rose (*Rosa*
spp.). In this area it may threaten rare plants such as Spalding's silene (*Silene spaldingii*), smallhead goldenweed (*Pyrrocoma liatriformis*), sagebrush Mariposa lily (*Calochortus macrocarpus* var. *maculosus*), and Idaho hawksbeard (*Crepis bakeri* ssp. *idahoensis*) [56].

In Montana, Russian knapweed was found growing in alfalfa and grain fields in Missouri River bottomlands in the north-central part of the state. Vegetation in the area included sagebrush (*Artemisia* spp.)-grassland (where dominants included western wheatgrass (*Pascopyrum smithii*), smooth brome (*Bromus inermis*), and Canada

wildrye (*Elymus canadensis*)); black greasewood; plains cottonwood (*Populus deltoides* ssp. *monilifera*); willow (*Salix* spp.) and "meadow" types. Plants associated with Russian knapweed included barley (*Hordeum* spp.), witchgrass (*Panicum capillare*), green bristlegrass (*Setaria viridis*), pigweed (*Amaranthus* spp.), *Chenopodium* spp., old-man's-whiskers (*Geum triflorum*), summer-cypress (*Kochia scoparia*), and common dandelion (*Taraxacum officinale*) [1]. Of 21 diverse sites in southwestern Montana dominated by curlleaf mountain-mahogany (*Cercocarpus ledifolius*), Russian knapweed occurred on 2 sites west of the Continental Divide in 1975 [26].

Middle Rocky Mountains:
In Wyoming Russian knapweed occurs on perennial grasslands dominated by blue grama (*Bouteloua gracilis*) [17].

In Colorado the most severe infestations of Russian knapweed occur in mountain and western slope counties, with lighter infestations associated with blue grama on the eastern plains [17]. Habitats in which Russian knapweed may be found include riparian woodlands dominated by cottonwood (*Populus* spp.), skunkbush sumac, and willow; riparian shrubland; and sagebrush/fourwing saltbush (*Atriplex canescens*) shrublands.

Great Basin:
In Utah, Russian knapweed is found in cottonwood/willow and tamarisk (*Tamarix* spp.) communities. In Nevada, Russian knapweed can be found with creosotebush (*Larrea tridentata*) and saltgrass, and it may threaten plants found in ash (*Fraxinus* spp.) meadows [56].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Acroptilon repens

GENERAL BOTANICAL CHARACTERISTICS:
Russian knapweed is a non-native, perennial, invasive forb that often forms dense, monotypic colonies from widely spreading horizontal roots. Roots are scaly and dark-brown to black in color, and can extend 14 square yards (12 m^2) radially, and up to 23 feet (7 m) deep within 2 growing seasons ([83,86] and sources therein). Records indicate that an infestation of Russian knapweed can survive 75+ years through its root system [83].

Russian knapweed shoot development originates from root-borne buds. A patch of Russian knapweed may have 9 to 27 shoots per square foot (100-300/m^2) [83]. Russian knapweed stems are thin, erect and openly branched, standing up to 3 feet (0.9 m) tall. Rosette leaves are 2 to 4 inches (5-10 cm) long and 0.4 to 1 inch (1-2.5 cm) wide. Leaves grow smaller near the tops of the stems. Flowerheads arise terminally and are 0.25 to 0.5 inch (0.6 to 1.3 cm) in diameter. Russian knapweed seeds are achenes and are oblong, 2.1 to 2.4 mm in length by 0.6 to 0.7 mm in width. Seeds are covered with many fine hairs and have a pappus on the apex ([83,86] and sources therein).

Several allelopathic compounds have been isolated form Russian knapweed [29,71,72]. It is known that allelopathy plays an important role in Russian knapweed ecology and that these compounds can interfere with the growth of associated plants [41].

RAUNKIAER [54] LIFE FORM:
Hemicryptophyte
Geophyte

REGENERATION PROCESSES:
Russian knapweed reproduces by seed and by adventitious buds on horizontally spreading roots. Since Russian knapweed produces relatively few seeds and lacks effective mechanisms for seed dispersal, local infestations increase primarily by adventitious roots [61,83,86].

Breeding system: Russian knapweed is monoecious and is an obligate outcrosser [36].

Pollination: Russian knapweed is insect pollinated [36,83].

Seed production:
A single Russian knapweed plant can produce about 1,200 seeds per year (Ivanova 1966, as cited by [83,86]). Watson [83] reported Russian knapweed seed production of about 100 seeds per plant per year along roadsides, and about 292 seeds per plant on rangeland in British Columbia, with a high ovule abortion rate. Beck [8] reports seed production of about 50 to 500 per shoot in Colorado. Flower production declines with decreasing light levels [22].

Seed dispersal:
Russian knapweed seedheads generally remain closed at maturity, and the relatively heavy seeds tend to lose the small pappus bristles at maturity; therefore, wind dispersal is an unlikely method for long-range seed dispersal [58,83]. Ballistic dispersal may be more important than wind dispersal: Mature achenes dehisce from the receptacle and usually remain in the involucre, but can be launched over distances roughly equal to the height of the plant when the involucre sways in a breeze [2]. The primary means of long-range seed dispersal is probably via contaminated hay and other seed (primarily alfalfa), or by movement of farm machinery or other vehicles [58,61].

Seed banking:
Seed banking of Russian knapweed is not reported in the literature. It is unclear how long Russian knapweed seeds can remain viable, as reports vary from 2 to 3 years (Ivanova 1966 as cited by [83]), while Andersen (1968) reported successful germination after 5 years of dry storage [17], and Selleck [66] reported successful germination of seeds after up to 9 years storage at room temperature.

Germination: Russian knapweed seeds do not germinate readily [58], and germination rarely occurs in the field [66,83]. An initial dormancy period has been observed in Russian knapweed seeds and can be broken by alternating temperatures. Russian knapweed seeds are able to germinate under a wide range of temperatures (33 to 95 degrees Fahrenheit (0.5-35 °C)) with optimum germination occurring between 68 and 86 degrees Fahrenheit (20-30 °C) ([83], and sources therein). Light is not essential for germination, but alternating light and darkness improves germination, and white light appears to stimulate germination [50].

Seedling establishment/growth: No information

Asexual regeneration:
Russian knapweed reproduces primarily by vegetative means, and can spread rapidly and form dense colonies. The root system consists of the taproot, 1 to many horizontal roots, and their vertical extensions. Buds on the horizontal roots can form adventitious shoots that can grow to be independent plants ([58,83,86] and sources therein). Spread can be hastened by cultivation [58].

SITE CHARACTERISTICS:
General:
Russian knapweed is commonly found along roadsides, railways, riverbanks, irrigation ditches, pastures, waste places, clearcuts, and croplands. It does not readily establish in healthy, natural habitats [17]. Because Russian

knapweed regenerates primarily vegetatively, it does not spread as readily alongside roads and trails as do other knapweeds [60]. In its native lands, Russian knapweed is weedy along roads and among crops, in abandoned areas and near dwellings (Klokov and others 1963, as cited by [58]). In Washington it may grow in hayfields, pastures, grainfields and irrigation ditches, and is reportedly not a problem weed on most rangelands [58].

Elevation:
There are few reports in the literature on the elevational range of Russian knapweed. It is primarily an invader of croplands. It can be found up to 8,600-9,300 feet (2,620-2,835 m) in its native land (Klokov and others 1963, as cited by [58]), and up to 6,300 feet (1,900 m) in California [37]. It has been observed between 4,025 to 7,850 feet (1,220-2,380 m) in Utah [85].

Moisture and temperature: Watson [83] reports a typical infestation of Russian knapweed in British Columbia with annual precipitation of 9.8 inches (245 mm) and mean summer temperature of 70.5 degrees Fahrenheit (21.4 °C) [55]. Fructan metabolism in Russian knapweed gives it a competitive advantage by facilitating growth at relatively cool temperatures when soil moisture is usually most plentiful [19]. Only relative descriptions of the moisture requirements of Russian knapweed are available in the literature. Observations in southeastern Colorado suggest that stands of Russian knapweed are denser where precipitation is "lower" [30]. Similarly, while Russian knapweed is found in both irrigated and arid areas in Canada, it is more common and more competitive in "drier" regions [66,83,86]. However, it has been documented as well established under irrigated conditions [83]. In Washington, Russian knapweed is most commonly found in areas with relatively high soil moisture content such as irrigated or irrigation runoff areas; near rivers, creeks, canals, coulees, and draws; on toeslopes; in deep, fine textured soils in high precipitation zones and valley bottoms; and in poorly drained soils [59]. Russian knapweed can tolerate some flooding, but not severe drought [58].

Soils:
In its native land, Russian knapweed grows on clayey, sandy or rocky steppes and sunny meadows, on saline soils, clayey, rocky, or sandy shores of lakes and rivers, on rocky and clayey slopes of hills, and on bottomlands (Klokov and others 1963, as cited by [58]). In Washington, Russian knapweed is often found on sites with either greater effective rooting depth or greater effective moisture than adjacent areas [21], and it tolerates saline and alkaline soils [58]. Russian knapweed occurs mostly in alkaline, seasonally wet habitats in Montana [43]. Researchers in Colorado have noted that while Russian knapweed can grow on a variety of soil types, it appears to be most competitive on soils with high clay content [30,61]. Goslee and others [32] suggest that the ability of Russian knapweed to dominate on fine-textured soils while forming a persistent mixture with other species on coarse soils may be due to allelopathy, since allelopathy is likely to have more impact on fine-textured soils.

Watson [83] reports that the northern limit of Russian knapweed in British Columbia is 54 °N, but that most infestations occur in the drier southern regions of British Columbia, Alberta, and Saskatchewan.

SUCCESSIONAL STATUS:
Watson [83] reports that Russian knapweed invades open, disturbed land and suppresses growth of surrounding plants. Goslee and others [32] suggest that because Russian knapweed produces few seeds and has poor dispersal mechanisms, it does not colonize new sites efficiently. Once established in open areas, however, it is highly competitive and spreads aggressively, often forming dense, single-species stands that can persist indefinitely [83]. Computer simulations suggest that the ability of Russian knapweed to dominate aboveground biomass in blue grama grassland is related to soil texture. Russian knapweed dominates clay soils within 30 years after establishment, will codominate with perennial grasses on clay-loam soils, but will not achieve dominance over perennial grasses on coarse-textured soils. These differences in dominance are related to differing allelopathic effects in different soil textures [32]. Russian knapweed is sensitive to decreased amounts of sunlight, does not compete well under a heavy canopy, and is weakened by dense shade [22,58,59]. Dall'Armellina and Zimdahl [22] found that the number of shoots and flowers produced by Russian knapweed in a greenhouse study was highly correlated with light level, and that shoot and root dry weight decreased with each light reduction. Leaf area increased with initial light reduction, but was reduced at the lowest light level. Disaccharide, inulin, and nitrogen concentrations also decreased in the roots of shaded plants ([83], and sources therein).

SEASONAL DEVELOPMENT:
Russian knapweed shoots emerge from perennial roots early in spring, shortly after soil temperatures remain above freezing. Plants form rosettes and bolt in late May to mid-June. Russian knapweed flowers from June to October in the U.S. and from July to September in Canada [83]. Seeds develop in late summer [86]. Flowering periods are given below.

State	Flowering dates	References
California	May-September	[49]
Illinois	June-August	[47]
North Dakota	late June	[73]
Utah	June-September	[85]
Washington	June-September	[58]
Great Plains	June-September	[33]

Concentrations of carbohydrate reserves in the roots of Russian knapweed follow a seasonal pattern. Disaccharide reserves decreased during the spring form 6.8 to 3.6% and peaked at 8.5% at the end of the growing season. Inulin content in Russian knapweed roots was 4.3% in the spring and 11% at the end of the growing season ([83], and sources therein).

FIRE ECOLOGY

SPECIES: Acroptilon repens

FIRE ECOLOGY OR ADAPTATIONS:
Fire adaptations:
Information regarding fire adaptations of Russian knapweed is not available in the literature. Russian knapweed has a deep-seated, extensive perennial root system that is likely to allow it to survive even severe fire, depending on site conditions. Russian knapweed is also capable of establishing from seed; however, the tolerance of the seeds to heating is unknown, and seed dispersal over any distance larger than the height of the plant requires a dispersal agent [2,58]. It is not known whether Russian knapweed is likely to establish from seed after fire.

Fire regimes:
Russian knapweed occurs primarily in agricultural communities in the western U.S. and southwestern Canada, where historic fire regimes have been dramatically altered. The historic fire regimes of the more native communities in which Russian knapweed sometimes occurs are of varied frequency and severity. Russian knapweed did not occur in these communities at the time in which historic fire regimes were functioning, but has established since fire exclusion began. It is unclear how historic fire regimes might affect Russian knapweed populations. It is also unclear how the presence of Russian knapweed might affect these fire regimes. Dense infestations of Russian knapweed may change the fire regime by changing the fuel characteristics and fire return interval at a given site. Research in this area is needed.

The following table provides some fire regime intervals for communities and ecosystems in which Russian knapweed may be found:

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [53]
basin big sagebrush	*A. tridentata* var. *tridentata*	12-43 [63]
mountain big sagebrush	*A. t.* var. *vaseyana*	15-40 [5,15,46]
Wyoming big sagebrush	*A. t.* var. *wyomingensis*	10-70 (40**) [79,89]
saltbush-greasewood	*Atriplex confertifolia-Sarcobatus vermiculatus*	< 35 to < 100
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100
plains grasslands	*B.* spp.	< 35
blue grama-needle-and-thread grass-western wheatgrass	*B. gracilis-Hesperostipa comata-Pascopyrum smithii*	< 35 [53]
curlleaf mountain-mahogany*	*Cercocarpus ledifolius*	13-1000 [6,65]
mountain-mahogany-Gambel oak scrub	*C. l.-Quercus gambelii*	< 35 to < 100
western juniper	*Juniperus occidentalis*	20-70
Rocky Mountain juniper	*J. scopulorum*	< 35
creosotebush	*Larrea tridentata*	< 35 to < 100
pinyon-juniper	*Pinus-Juniperus* spp.	< 35 [53]
mountain grasslands	*Pseudoroegneria spicata*	3-40 (10**) [3,4]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [24,82]

*fire return interval varies widely; trends in variation are noted in the species summary
**mean

POSTFIRE REGENERATION STRATEGY [74]:
Geophyte, growing points deep in soil
Secondary colonizer (on-site or off-site seed sources)

FIRE EFFECTS

SPECIES: Acroptilon repens

IMMEDIATE FIRE EFFECT ON PLANT:
Russian knapweed is probably top-killed by fire, while the roots are likely to remain unharmed. It is not known how Russian knapweed seeds are affected by exposure to heat. Research is needed in this area.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
Researchers in Wyoming burned plots of Russian knapweed after first mowing them to a height of 3 to 5 inches

(8-12 cm). Observations made following these treatments suggest that Russian knapweed plants were injured to a depth of 2.5-4 cm below the soil surface, and that lateral roots at the 7.5 to 15 cm depth did not appear to be injured. Russian knapweed seedheads were also burned but the seed "appeared to be viable". However, Russian knapweed seedlings were not observed after burning [14].

PLANT RESPONSE TO FIRE:
Russian knapweed probably sprouts from root buds after fire, and may establish from on-site seed or from seed brought on site by people, animals, or vehicles.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
No entry

FIRE MANAGEMENT CONSIDERATIONS:
Fire as a control agent:
The only study in the literature that reports results from burning Russian knapweed states that it is not effectively controlled by burning [12]. However, the experimental methods used in this study were not clearly reported, and there was no mention of how the burning was carried out. It is stated in the introduction to this paper that Russian knapweed infested areas "must be tilled before newly established grass seedlings can survive. Without tillage, grass seedlings can survive only after Russian knapweed residues have been exposed to moisture for two growing seasons." No experimental evidence is given, however, to support this assertion [12]. If it is valid, one might consider researching the use of prescribed burning of plant residues to volatilize allelopathic compounds.

Postfire colonization potential:
There is no information in the literature regarding the postfire colonization potential of Russian knapweed; however, general precautions should be followed to prevent establishment after fire. The USDA Forest Service's "Guide to noxious weed prevention practices" [76] provides several fire management considerations for weed prevention in general that may apply to Russian knapweed. Wildfire managers might consider including weed prevention education and providing weed identification aids during fire training; avoiding known weed infestations when locating firelines, monitoring camps, staging areas, helibases, etc., to be sure they are kept weed free; taking care that equipment is weed free; incorporating weed prevention into fire rehabilitation plans; and acquiring restoration funding.

When planning a prescribed burn, preinventory the project area and evaluate cover and phenology of any Russian knapweed present on or adjacent to the site, and avoid ignition and burning in areas at high risk for Russian knapweed establishment or spread. Avoid creating soil conditions that promote weed germination and establishment. Discuss weed status and risks in burn rehabilitation plans [76].

To prevent infestation, re-establish vegetation on bare ground as soon after fire as possible, using either natural recovery or artificial techniques as appropriate to site conditions and objectives. When reseeding after wildfires and prescribed burns, use only certified weed-free seed. Monitor the burn site and associated disturbed areas after the fire and the following spring for emergence of Russian knapweed, and treat to eradicate any emergent Russian knapweed plants. Regulate human, pack animal, and livestock entry into burned areas at risk for weed invasion until desirable site vegetation has recovered sufficiently to resist weed invasion. Additional guidelines and specific recommendations and requirements are available [76].

MANAGEMENT CONSIDERATIONS

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IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Russian knapweed is generally avoided by grazing animals due to its bitter taste [83]. Prolonged ingestion (more than 30 to 60 days) of Russian knapweed by horses causes a fatal neurological disorder, nigropallidal encephalomalacia, when cumulative plant quantities of 60 to 200% of the animal's body weight are consumed [52,57].

Examination of feeding sites and analysis of rumen contents indicate some use of Russian knapweed by white-tailed deer in north-central Montana in the summer and winter months [1]. Russian knapweed is considered important forage for Rocky Mountain bighorn sheep in British Columbia [7]. Birds and rodents eat the seeds [58].

PALATABILITY:
Russian knapweed is avoided by grazing animals due to its bitter taste. It is so bitter that as little as 0.01% contamination by weight reduces the quality of flour and other grain products [83].

NUTRITIONAL VALUE:
No information

COVER VALUE:
No information

OTHER USES:
No information

IMPACTS AND CONTROL:
Impacts: Russian knapweed is considered a serious habitat invader [86]. A single patch or infestation of Russian knapweed can grow quite rapidly. Once established, it can form dense infestations that reduce desirable vegetation through a combination of competition and allelopathy [45,86]. Both roots and leaves of Russian knapweed have been found to produce chemicals inhibitory to the germination and growth of other species [9,29,41,71,72]. The presence of Russian knapweed can thereby reduce forage for livestock and biodiversity for wildlife habitat [86]. Russian knapweed plants, ingested in sufficient quantities as fresh or dried forage, are toxic to horses causing the neurological disorder nigropallidal encephalomalacia [52,57]. The presence of Russian knapweed in hay decreases its feed and market value [61,83].

Whitson [86] claims an 11% average annual increase of infestations in Wyoming. See the "Distribution and Occurrence" section of this report for current estimations of infested acres for several western states. Olson [51] and Griffith [34] provide guidelines and methods for estimating the ecologic and economic impact of noxious weeds on rangelands.

Control:
Russian knapweed has a competitive advantage in a variety of environments, and will continue to persist unless it is suppressed long enough to allow the introduction and establishment of desirable species [13,17]. Continued monitoring and follow-up treatments must be conducted at least annually to eliminate reinfestation of Russian knapweed [17,61].

Keys to controlling Russian knapweed are 1) stressing the plant and causing it to expend nutrient reserves in its root system [8], 2) eliminating new seed production, and 3) controlling its vegetative spread by planting competitive species and/or isolating the infestation so as not to spread root fragments to other locations during

treatment. If sufficient human resources are available, mechanical control is a good place to start. Hand pulling or cutting the plants to kill the tops will starve the roots if done repeatedly, every time they sprout [61]. Continued vigilance is necessary since removed aerial parts are rapidly regenerated from vegetative buds on the roots [83].

Integrated weed management:
Managers are encouraged to integrate control methods that complement one another. Integrated management includes considerations of not only killing the target plant, but also of establishing desirable species and maintaining weed-free systems over the long term. Factors to be addressed before a management decision is made include inventory and assessment to identify the target weed(s) and determine the size of the infestation(s); assessment of nontarget vegetation, soil types, climatic conditions, and important water resources; and an evaluation of the benefits and limitations of each control method [48]. Components of any integrated weed management program are sustained effort, constant evaluation, and the adoption of improved strategies [67].

Conceptual models can be developed to determine the probability that the weed management strategy will result in the desired plant community, based on the life histories and population dynamics of the species in the existing plant community [68]. A weed management strategy may include designed disturbance (e.g. mechanical or chemical control), controlled colonization (e.g. planting competitive species), and controlled species performance (e.g. biological control) [10,68,88]. An integrated management plan for Russian knapweed includes efforts to place continual stress on the plant [8].

Prevention:
The most efficient and effective method of managing invasive species is to prevent their invasion and spread [69]. The fact that Russian knapweed became established wherever Turkestan alfalfa seed was planted suggests that only seed that has been cleaned and tested for purity should be used [61]. Preventing the establishment of Russian knapweed in natural areas is achieved by maintaining healthy natural communities and by conducting aggressive monitoring at least 3 times each year [17]. Begin monitoring in spring (late May to mid-June) when the plants have recently bolted; next in the summer (July) to find any missed plants that have flowered and are easily recognizable; and finally in the fall (late August or early September) to find any late-blooming plants that might have regrown from the root system of plants that had been pulled during an earlier search. Monitoring efforts are best concentrated on the most disturbed areas in a site, particularly along roadsides, parking lots, fencelines, and waterways. When an infestation is found, the location can be recorded and the surrounding area surveyed to determine the size and extent of the infestation, so these sites can be revisited on follow-up surveys [17]. For more on monitoring see Johnson [38]. It is important to kill whatever plants are found, followed by some combination of mechanical, chemical and/or biological control [17].

Weed prevention and control can be incorporated into all types of management plans, including logging and site preparation, management of grazing allotments, recreation management, research projects, road building and maintenance, and fire management [76]. See the "Guide to noxious weed prevention practices" [76] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

Physical or mechanical control:
Removal of the aboveground portion of Russian knapweed plants reduces the current year's growth and will eliminate seed production for that year, but it will not kill the roots of Russian knapweed. Cutting, mowing or disking Russian knapweed infestations several times annually will control the existing topgrowth. Often, the plants that reemerge are smaller in size and lower in vigor. This is a good indication that the plants are under stress and that their nutrient reserves are declining [17]. Cutting (or mowing) 3 times a year (spring, summer, fall) stresses Russian knapweed plants and forces them to use nutrient reserves stored in the root system. Unless repeated frequently, the cut plants recover vigorously the following year [8]. Mowing can also damage surrounding plants and is not likely to be feasible in natural areas [17]. Mowing twice during the growing season in Wyoming was not effective in controlling Russian knapweed [10]. Mowing may stimulate regeneration of aerial parts and prevent dehydration of underground organs (Tarshis 1967, as cited by [83]).

Cutting is slightly less effective than pulling since cutting does not remove any portion of the Russian knapweed

root. Pulling plants 2 to 3 times annually contained, but did not eliminate, a Russian knapweed infestation in Washington (Youtie 1998, as cited by [17]). Cutting roots for 3 years to a depth of 12 inches (30 cm) can destroy the root system in the top meter of soil. Root fragments up to 16 inches (40 cm) long are killed by burial below 12 inches (30 cm), indicating some control by deep plowing ([83], and sources therein).

Early control attempts involved starving the roots by smothering with straw and manure, which worked on small patches when materials were thick enough to prevent stems from penetrating through to sunlight. Sheet metal and paper have also been used successfully to control small patches [61], indicating that solarization with black plastic may be effective for controlling Russian knapweed, especially since its growth form causes it to occur in patches.

Fire:
See "Fire Management Considerations: Fire as a control agent" in the FIRE EFFECTS section of this summary.

Biological: *Subanguina picridis*, a gall-forming nematode, is the first biological control agent approved for release on Russian knapweed and is established at limited sites in Colorado, Montana, New Mexico, Oregon, Utah, Washington, Wyoming, Alberta, and British Columbia [25]. *Subanguina picridis* has not proven to be an effective agent under field conditions. Additional agents are being sought and tested [44,62,64]. The biology, gall morphology and physiology, and effectiveness in weed control of *S. picridis* are discussed by Harris and Shorthouse [35] and Rosenthal [62].

Grazing is not a viable method of control for Russian knapweed since the plant is generally avoided by grazing animals and can be poisonous to horses. When Russian knapweed is present on horse pasture, it must be removed or fenced off to prevent horses from eating it.

Chemical:
Before using herbicides for control of invasive plants, managers must consider the effectiveness of the herbicide on the target plant, appropriate timing and rates of application, the potential impacts on nontarget organisms, and residual activity and toxicity of the herbicide. If chemical control is used it must be incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations [16]. Use of herbicides may be limited in natural areas. See the Weed Control Methods Handbook
for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

In most situations, Russian knapweed cannot be effectively managed by herbicide alone [8]. Chemical control of Russian knapweed has proven more difficult than that of other knapweed species [58]. However, herbicide treatments may stress the plant enough to give desirable plants a competitive advantage [8,10]. Herbicides evaluated for control of Russian knapweed include 2,4-D, picloram, dicamba, clopyralid, glyphosate, and combinations thereof. Comparative trials designed to evaluate chemicals, combinations, rates, and/or timings are available [23,28,80]. Carpenter and Murray [17] give a synopsis of the effects of picloram, clopyralid, and glyphosate on Russian knapweed and associated species, available online (Russian knapweed - Element Stewardship Abstract). Benz and others [10] evaluated several chemicals with and without seeding of "improved" grass species. Best results were obtained with clopyralid + 2,4-D and 'Sodar' thickspike wheatgrass (*Elymus lanceolatus*) [10]. Carpenter [18] includes extensive data on the effects of different rates of picloram, clopyralid, and metsulfuron on the density of nontarget plants from several families.

Cultural: Russian knapweed is sensitive to light competition [22], and crops that produce dense shade under irrigation (e.g. alfalfa) have been successfully used to suppress Russian knapweed [59]. Any treatment that provides control of Russian knapweed must either release competitive species present in the understory or be combined with reseeding before long-term sustainable control can be achieved [86,87]. When perennial grasses such as western wheatgrass and blue grama were present in the understory, single applications of picloram resulted in 85% control of Russian knapweed 8 years following treatment. When sites that lacked a desirable understory were similarly treated, annual weeds replaced Russian knapweed. Two applications of picloram and clopyralid before seeding and 1 application 1 year after seeding with wheatgrass (Triticaceae) species and

Russian wildrye provided control up to 5 years after seeding [87]. Herbicide application and planting of Russian wildrye provided a competitive monoculture 7 to 9 years after treatment in Wyoming. The dense, fibrous root system of Russian wildrye may give it a competitive advantage in the capture of moisture and nutrients and physically inhibit the entry of Russian knapweed lateral roots [12,13].

Whitson [86] suggests that the use of herbicides to control Russian knapweed before establishing perennial grasses can be an important part of a management system. Benz and others [10] found that seeded grass species needed an initial control treatment of Russian knapweed in Wyoming old fields before they could establish. It has also been suggested that tillage of Russian knapweed surface residue is necessary to hasten the decomposition of allelochemicals before planting competitive species [8,12,86], although no experimental evidence was given to support this assertion. Furthermore, experimental evidence provided by Bottoms and Whitson [12] suggests that grass cover is similar between tilled and untilled plots, and that "the only significant treatment providing both yield and control was nontilled Russian wildrye treated with picloram." Tilling is not possible or appropriate for most natural areas [17]. The non-native smooth brome competes well with young Russian knapweed shoots and is somewhat tolerant to the growth inhibitors in the soil [8]. Unfortunately, smooth brome is itself invasive in many grassland and meadow habitats across North America [17].

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