Euonymus fortunei

INTRODUCTORY

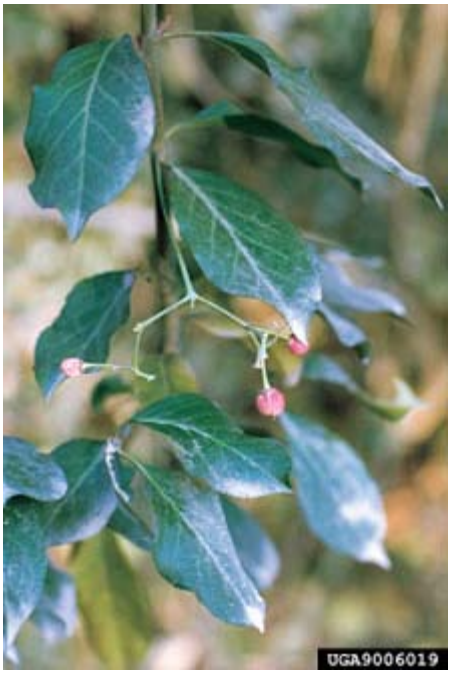

Photo by Keith Langdon, National Park Service, Bugwood.org

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FEIS ABBREVIATION:
EUOFOR

NRCS PLANT CODE [69]:
EUFO5
EUFOF
EUFOR2

COMMON NAMES:

wintercreeper
Chinese spindle-tree
climbing euonymus

TAXONOMY:
The scientific name of wintercreeper is *Euonymus fortunei* (Turcz.) Hand.-Maz. (Celastraceae) [3,18,22,33,42,46,73,76].

Although not distinguished in local floras, Kartesz [33] recognizes 2 varieties in North America:
Euonymus fortunei (Turcz.) Hand.-Maz. var. *fortunei*
Euonymus fortunei (Turcz.) Hand.-Maz. var. *radicans* (Sieb. ex Miq.) Rehd.

A review by Dirr [17] describes another variety in the United States, *E. f.* var. *coloratus*, which he says is often listed as the cultivar 'Coloratus'. Dirr [17] describes 51 cultivars of *E. fortunei*. A review by Blakelock [2] describes several varieties and forms of *E. fortunei*, occurring mostly in Asia or as cultivars, distinguished primarily by leaf characteristics. The Flora of China states "Numerous taxa have been named within the *E. fortunei* complex but many of these refer to cultivated plants and are best treated as cultivars" [76]. In this review, *E. fortunei* is referred to as "wintercreeper", varieties are referred to by scientific name, and cultivars, when identified as such in the literature, are referred to by cultivar name in single quotation marks (e.g., 'Emerald and Gold').

SYNONYMS:
for ***Euonymus fortunei* var. *radicans*** [33]:
Euonymus radicans [50]

LIFE FORM:
Liana-shrub

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
Information on state-level noxious weed status of plants in the United States is available at Plants Database.

DISTRIBUTION AND OCCURRENCE

SPECIES: Euonymus fortunei

GENERAL DISTRIBUTION:
Wintercreeper is native to China ([76], reviews by [1,62,73]) and was introduced to North America as an ornamental ground cover in 1907 (reviews by [1,29,52,54]). It has escaped cultivation and established in scattered areas in the central and eastern United States (reviews by [1,52,54]). According to distribution maps provided by Plants Database, in Canada wintercreeper occurs only in Ontario, and in the United States it occurs from Maryland to Wisconsin, south to Georgia and Mississippi (with the exception of West Virginia), and west to Missouri and Nebraska. The distribution of *E. f.* var *radicans* is identical to that of the species; while *E. f.* var *fortunei* occurs only in Maryland and Illinois [69]. Wintercreeper, along with several other horticultural plant species, is susceptible to attack by a fungal parasite that is native to and occurs only in the southwestern United States and adjacent Mexico (Duffield and Jones 1998 as cited by [40]). This fungus, Texas root rot (*Phymatotrichum omnivorum*), may exert a strong influence on plant invasions in that region [40].

Local floras and other references report varying frequency of escape from cultivation among areas where wintercreeper occurs, suggesting a scattered and disjunct pattern of distribution. Wintercreeper occasionally escapes in the northeastern United States [22,42]. It was observed and described as "naturalized" along the west bank of Rock Run near Plummers Island in Maryland around 2003 [56]. It appeared "sporadically" as escapes in Ohio as of 1961 [3] and "seldom" escaped in Michigan as of 1985 [73]. It was a newly reported component of the flora in Illinois sometime between 1956 and 1978 [27], listed in only 1 county there in 1978 [47], and described as "infrequently escaped from cultivation and scattered" in 1986 [46]. A 1990 review by Hutchison [29] reports that wintercreeper occurred mostly near urban centers in Illinois, with reports from several sites in the East St Louis area. It was common throughout Giant City State Park and Fern Rocks Nature Preserve in Jackson County, Illinois, and near Karnak in Pulaski County [29]. Wintercreeper was not described the flora of the Carolinas (1968), but the flora states that various horticultural species of *Euonymus* (including wintercreeper) "may persist around old homesites or may rarely escape from cultivation" [50].

Forest Inventory and Analysis (FIA) data from forests in 12 southern states indicate that wintercreeper was detected in only 5 states and was most common in Kentucky and Tennessee [44]:

Estimated acres covered by wintercreeper in forests in the southern United States, summed from subplots within each state using the Southern Research Station's Forest Inventory and Analysis database from 15 March 2008 [44]

AL	AR	FL	GA	KY	LA	MS	NC	SC	TN	TX	VA
0	82	0	0	6,644	0	0	164	0	4,328	0	7

HABITAT TYPES AND PLANT COMMUNITIES:
Plant community associations of nonnative species are often difficult to describe accurately because detailed survey information is lacking, there are gaps in understanding of nonnative species' ecological relationships, and nonnative species may still be expanding their North American range. Therefore, wintercreeper may occur in plant communities other than those discussed here and listed in the Fire Regime Table.

Wintercreeper is most commonly reported as occurring near homesites and disturbed areas (see Site Characteristics) and in forests and woodlands. In its native China, wintercreeper is common in woodlands, scrub, and forests [76]. In North America, it has spread into upland and lowland forests in the eastern and central parts of the United States (review by [54]). A review by Grese [24] lists wintercreeper as a problem species in forest communities in the United States but not in open or wetland communities; however, it may also occur in open communities (personal communication [32], [59]) such as savannas and grasslands (personal communication [63]).

Wintercreeper occurs in forests and woodlots in the Great Lakes states. It was collected in an oak woods west of Marshall, Michigan in 1984, where it evidently (based on juvenile foliage) had established from seed [73]. Wintercreeper occurred in forests dominated by sugar maple and American beech in central Indiana [7], and it occurred in disturbed woodlots in Indianapolis that were dominated by maples (*Acer* spp.), oaks, elms (*Ulmus* spp.), ashes (*Fraxinus* spp.), and hickories. These woodlots had evidence of extensive human impact and supported several other nonnative and invasive plant species [53]. According to a review by Hutchison [30], wintercreeper has spread into many types of forest in Illinois, including floodplain, mesic, and dry-mesic forests.

In the mid-Atlantic region, wintercreeper may occur in oak-pine (*Quercus-Pinus*), oak-hickory (*Quercus-Carya*), and mixed mesophytic forests characterized by tree species such as American beech (*Fagus grandifolia*), yellow-poplar (*Liriodendron tulipifera*), yellow buckeye (*Aesculus flava*), sugar maple (*Acer saccharum*), white oak (*Quercus alba*), northern red oak (*Q. rubra*), and black walnut (*Juglans nigra*) among others (personal communication [63]). Wintercreeper was occasional in mature, second-growth oak-hickory forest and edge habitat in Rock Creek Park in Washington, DC, where common canopy species included a variety of oaks (*Quercus* spp.), American beech, yellow-poplar, hickories (*Carya* spp.), and red maple (*Acer rubrum*) [20]. Wintercreeper did not occur in Strounds Run State Park in southern Ohio in 1957, but was listed as a "naturalized alien" there in a study published in 2006. It was described as "rare": occurring in only 1 or 2 locations. It occurred on mesic ravines and/or stream terraces that were generally occupied by mixed mesophytic forests dominated by red maple, silver maple (*A. saccharinum*), shagbark

hickory (*C. ovata*), American beech, green ash (*Fraxinus pennsylvanica*), yellow-poplar, black cherry (*Prunus serotina*), and northern red oak [26]. At Stones River National Battlefield in Tennessee, wintercreeper occurs in the Interior Plateau chinquapin oak-Shumard oak (*Quercus muehlenbergii-Quercus shumardii*) forest association. These dry-mesic forests are codominated by varying proportions of shagbark hickory, Carolina shagbark hickory (*Carya carolinae-septentrionalis*), eastern redcedar (*Juniperus virginiana* var. *virginiana*), and sugarberry (*Celtis laevigata*). In addition to wintercreeper, other nonnative plant species occurring in this community include Amur honeysuckle (*Lonicera maackii*), Japanese honeysuckle (*Lonicera japonica*), privets (*Ligustrum sinense*, *Ligustrum vulgare*), and tree-of-heaven (*Ailanthus altissima*). This forest association is considered globally rare, and most, if not all, high-quality examples have been eliminated or severely impacted by timber removal, grazing, soil erosion, and fire exclusion. Other threats include windthrow, microclimate modification from intensive silvicultural practices on adjacent uplands, forest type conversion, and herbicide use [49].

A review by Stocker and Hupp [61] suggests that wintercreeper is potentially invasive in oak-hickory woodland in the southeastern United States.

Wintercreeper may also occur in more open plant communities (personal communications [32,63]). Wintercreeper occurred but was rare on the Potomac River Lowland in Piscataway and Fort Washington National Parks in Maryland. Here it occurred on sandy beach berms in communities dominated by calamus (*Acorus calamus*), narrow-leaved cattail (*Typha angustifolia*), and other marsh species, in areas where silver maple, green ash, and poison-ivy (*Toxicodendron radicans*) also occurred [59].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Euonymus fortunei

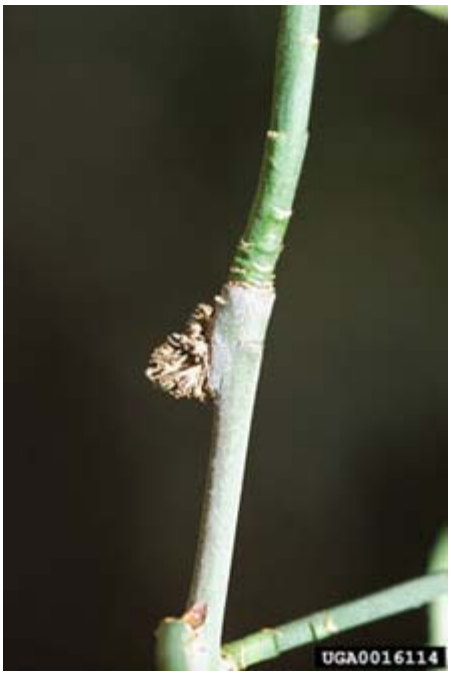
GENERAL BOTANICAL CHARACTERISTICS:

Botanical description: This description provides characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [22,46,73]).

Wintercreeper is a perennial, typically evergreen, trailing or climbing (by aerial, adventitious roots) liana, subshrub, or shrub [1,3,22,30,46,52,73,76]. Stems are narrow [52] and minutely warty [1,52,73]. Wintercreeper leaves are densely arranged on branches [76], opposite, ovate to elliptic, leathery, and vary from 1 to 2.5 inches (2.5-6.5 cm) long [1,3,46,52,54]. Leaves may be petiolate [22], with a petiole 2 to 9 mm long, but are sometimes sessile [76].

According to reviews, wintercreeper seldom flowers [73], and flowers occur only on adult types [17]. Observations in Kentucky, however, indicate that wintercreeper flowers and fruits consistently and prolifically from year to year (personal communication [63]). See Flower and seed production for further details. Flowers are inconspicuous [1,17,52], perfect [17,22,46], and occur in cymes [1,22,46,52] with few to several flowers [3]. Wintercreeper fruits are smooth, dehiscent capsules [3,22,46], about 5 to 6 mm in diameter [76]. Its seeds are enclosed in a fleshy, colorful aril [3,17,22,73].

Wintercreeper stems have abundant aerial rootlets or trailing roots [1,52] that form at nodes [46]. Aerial rootlets aid wintercreeper plants in climbing vertical surfaces [1,3,73] or form independent plants by sprouting along the ground surface [1].



Stem with aerial roots in May

Photo by James H. Miller, USDA Forest Service, Bugwood.org

The numerous cultivars of wintercreeper vary mostly in leaf size and color (reviews by [12,17,29]) but may also vary in plant size, growth form, and fruit production (review by [17]).

Growth form and population structure: Wintercreeper plants can form dense groundcover [1,29,43,52] trailing to 20 or more feet (6 m) [1,29], climb 40- to 70-foot-tall (12-21 m) vertical surfaces with the aid of aerial roots [17,43,52], or grow as shrubs up to 3 feet (1 m) tall [1,29,43,52].

Photo by James H. Miller, USDA Forest Service, Bugwood.org

When growing as a groundcover, independent wintercreeper plants originate from rootlets at short intervals along procumbent stems. Established populations appear as a dense mat of vegetation (reviews by [1,12,52]) that may impede the growth of native seedlings. As a liana, wintercreeper may climb rocks, trees, or other supporting structures. It may overtop trees, covering tree leaves and preventing photosynthesis (review by [52]). See Impacts for additional information.

Photo by Chris Evans, River to River CWMA, Bugwood.org

Wintercreeper growth and architecture may be altered after plants are damaged. Wintercreeper cultivar 'Coloratus'

plants damaged by rabbits in a nursery in Arkansas in fall and winter had lower canopy cover in March than the previous November; however, plants damaged by rabbits saw a considerable regrowth of stems and leaves from March through May. New spring growth nearly tripled previous growth percentages due to the unique architecture of second-year growth, which produced lateral stems with additional leaves on existing nodes [58].

Raunkiaer [51] life form:
Phanerophyte
Chamaephyte
Geophyte

SEASONAL DEVELOPMENT:
According to a review by Bean and McClellan [1], because wintercreeper is evergreen and begins growing before other vegetation emerges, it outcompetes existing vegetation for available space and resources.

In North America, wintercreeper generally flowers in the summer (June to July) and produces mature fruits by fall (reviews by [12,17,43,52,54]), though flowering and fruiting may occur earlier at lower latitudes (see table below). According to a review by Dirr [17], fruits mature October to November and often persist.

Flowering and fruiting dates for wintercreeper by area

Area	Flowering dates	Fruiting dates
Illinois	July-August [46]	---*
Tennessee	May-June	June-July [1]
Northeastern United States and adjacent Canada	June or July [22]	---
China	April-July	September-December [76]

*No data.

Wintercreeper may abscise a few leaves throughout the year, but most abscission occurs in early spring (unpublished data cited by [10]).

REGENERATION PROCESSES:
Wintercreeper regenerates sexually by producing fruits that are readily dispersed by birds, and vegetatively through long branches and lateral shoots that root at the nodes and form independent plants (reviews by [1,12,52]).

Pollination and breeding system: Wintercreeper flowers are perfect [17,22,46]. No additional information is available on this topic.

Flower and seed production: As of 2009 very little published information was available regarding seed production in wintercreeper. According to reviews, wintercreeper seldom flowers [73], and flowers occur only on adult types [17]. Observations in Kentucky, however, indicate that wintercreeper flowers and fruits consistently and prolifically from year to year (personal communication [63]). In order to flower and produce seed, wintercreeper must climb trees or other objects to get more sunlight. If no uprights are present, it does not obtain the liana diameter (approximately 1cm or greater) that triggers flowering (personal communication [63]). Climbing stems of wintercreeper typically flower in summer and produce mature fruit in fall (see Seasonal Development). Groundcover populations seldom, if ever, flower and fruit (reviews by [12,17,54]). Because it can form extensive groundcover without developing upright, climbing stems, it probably appears that it does not readily flower in many areas (personal communication [63]).

Seed dispersal: Wintercreeper seeds are equipped with arils that are readily eaten by birds and other wildlife, which then disperse the seed (reviews by [12,30,52], personal communication [63]), possibly many miles away [54]. Muhlenbach [48] recorded the occurrence of a few specimens of wintercreeper (*E. f.* var. *radicans*) on one site along

the railroad in St Louis, Missouri, in 1969. He notes that although this species was often cultivated as a ground cover in St Louis, there were no gardens in the vicinity [48], suggesting long-distance dispersal. Similarly, wintercreeper's presence in fragmented old-growth forests in Indiana suggests some form of long-distance dispersal because it is not an agricultural weed, and these forests were bordered mostly by corn and soybean fields [7].

On an old farm site in Kentucky with large scattered trees, the understory is covered by dense growth of the nonnative invasive species multiflora rose (*Rosa multiflora*), winged burning bush (*Euonymus alatus*), wintercreeper, and Oriental bittersweet (*Celastrus orbiculatus*). All of these species have bird-dispersed seed, suggesting that birds using the large old trees as perches "planted" seeds of the invasives (personal communication [63]).

Wintercreeper may also be dispersed by water. A review by Remaley [52] states that it "escapes from neglected gardens and is carried by water to undisturbed forest and riparian areas".

Seed banking: No information is available regarding occurrence or longevity of wintercreeper seed in the seed bank.

Germination: As of 2009, no information was available regarding germination of wintercreeper in the field; however, a review by Dirr [17] suggests that wintercreeper seeds have dormant embryos and recommends moist stratification at cold temperatures for propagation.

Seedling establishment: No information is available on requirements for wintercreeper seedling establishment, but it is capable of establishing on disturbed, relatively inhospitable sites (see photo below).

Wintercreeper plant growing from crack in pavement, at least 0.5 mile (km) from the nearest established, fruiting plants.
Photo courtesy of David Taylor.

Plant growth: A review by Dirr [17] suggests that wintercreeper has a "fast" growth rate. A nursery study in northwestern Arkansas using the cultivar 'Coloratus' reported that wintercreeper covered almost 75% of its plots with dense foliage within 1 year when grown in beds prepared with mushroom compost and watered from June to September (during establishment) [58]. Wintercreeper growth may be affected by a number of factors, including degree of shading (see Shade tolerance) and damage caused by vertebrates, insects, or water stress.

Wintercreeper cultivar 'Coloratus' plants damaged by rabbits in fall and winter showed "considerable" regrowth of stems and leaves from March through May, nearly tripling previous growth percentages [58].

Insect damage and water stress can both influence wintercreeper growth. Field experiments using the wintercreeper

cultivar 'Coloratus' suggest that euonymus scales, primarily the males feeding on the leaves, damage the leaf tissue so that the leaves have a higher than normal diffusive resistance and a lower transpiration rate, which eventually leads to increased leaf abscission and impaired growth of root tissue, especially when compounded by water stress [10]. The euonymus scale is native to eastern Asia and is associated with *Euonymus* spp. throughout most of their native and cultivated range (review by [10]). A greenhouse and field study found that both scale-infested and water-stressed wintercreeper plants abscised leaves whereas uninfested, unstressed plants did not; and there was a synergistic effect on leaf abscission from the 2 stresses combined [10]. Wintercreeper may abscise a few leaves throughout the year, but most abscission occurs in early spring (unpublished data cited by [10]). Greenhouse experiments using the wintercreeper cultivar 'Emerald and Gold' found that leaves began to abscise from water-stressed plants 61 days after infestation and 2 days after the soil water potential reached -1.7 MPa. Feeding by 2 generations of scales on non-water-stressed plants did not reduce total stem growth or significantly reduce intact leaf tissue, but infested plants had lower mean root weight than controls (P=0.05). Water-stressed plants—both infested and uninfested— were shorter, had lower mean root weight, and lower mean intact leaf weight than unstressed plants. Scale infestation significantly decreased the amount of leaf tissue remaining on water-stressed plants (P=0.05). Plants subjected to both water stress and scale infestation abscise more leaves than those exposed to either stress alone, apparently because scale feeding damage causes a heightened sensitivity to other stresses [10].

Vegetative regeneration:
Wintercreeper spreads vegetatively by producing lateral shoots along the main branches and establishing new, independent plants that emerge from rootlets occurring along procumbent stems at short intervals (reviews by [1,12,52]). When cut, wintercreeper sprouts from roots (review by [52]), root crowns, and/or cut stems (review by [17], personal communication [63]). In a nursery study, 'Coloratus' plants damaged by rabbits in fall had considerable regrowth of lateral stems and additional leaves from existing nodes the following spring [58].

Stem with distinctive buds in May

Photo by James H. Miller, USDA Forest Service, Bugwood.org

SITE CHARACTERISTICS:
Much of the information regarding site tolerances of wintercreeper comes from reviews [1,12,17,30,52,54,62] in which the source of the original information is not given or not clear, and it appears that they mostly cite one another. Very little primary information from field observations was found in the available literature as of 2009. No information was found describing invasive populations: on sites where wintercreeper occurred it was typically described as occasional or rare. Thus the following description does not necessarily describe sites where wintercreeper is most likely to be invasive.

Disturbance: As a popular ornamental plant, wintercreeper is usually associated with human habitation and disturbance. Wintercreeper was scarce and occurred only in disturbed areas including park facilities, clearings, and old homesteads at Fall Creek Falls State Park in Tennessee [19]. It occurred in an urban woodland surveyed in 1987 at the Wave Hill Natural Area in Bronx, New York [77], and in disturbed woodlots in Indianapolis that had evidence of extensive human impact and supported several other nonnative and invasive plant species [53]. One of two collections of wintercreeper in Michigan was from a gravel pit on dumped roadside debris in Benzie County, in 1982 [73]. From

home sites where it was planted, wintercreeper sometimes escapes cultivation and establishes, persists, and spreads in surrounding forests, woodlands [1,29,30], riparian communities [1,26,39], and other natural areas (see Habitat Types and Plant Communities). In central Kentucky, wintercreeper is most abundant in older neighborhoods and along country roads, where it frequently covers the trunk and lower third of the crown of old roadside trees (personal communication [63]).

Landforms and climate: As of 2009, no information describing landform preferences or climate tolerances was found in the available literature. According to Schwegman [54] wintercreeper has spread into forests and rocky bluffs in the eastern and central parts of the United States from Chicago southward, although it also occurs in Michigan [73]. Detrended correspondence analysis suggests an association of wintercreeper with floodplains in the eastern United States [39]. Wintercreeper is listed as occurring in coastal plain habitats on hydric and mesic sites in Virginia [72]. In a field study of old-growth forests in central Indiana, wintercreeper occurred on 2 of 14 edges surveyed and was somewhat more common on warm (south- or west-facing) edges than on cool (north or east-facing) edges [7]. Wintercreeper is occasional in deciduous forest and edge habitat in Rock Creek Park in Washington, DC, where the climate is continental, with warm, humid summers and mild to cold winters. The lowest average monthly temperature is 43.5 °F (6.4 °C) in January, and the highest average monthly temperature is 88.2 °F (31.2 °C) in July [20]. Dirr [17] indicates that wintercreeper can grow in USDA Hardiness Zone 4, where the average minimum temperature reaches -30 to -20 °F (-34 to -29 °C), but it is not "happy" there unless provided snow cover or winter shade. It better fits USDA Hardiness Zone 5 (average annual minimum teperature of -20 to -10 °F (-29 to -23 °C)) to Zone 8 or 9 (average annual minimum teperature of 20 to 30 °F (-7 to -1 °C)) [17].

No information on wintercreeper's elevational range in North America was found in the available literature as of 2009. In its native China, wintercreeper occurs from near sea level to 11,155 feet (3,400 m) [76].

Soils: According to reviews, wintercreeper is a popular landscape plant due to its rapid growth [1,17] and its ability to tolerate a variety of environmental conditions including heavy shade [1,12,17,30,52], poor soils, and variable pH [1,12,17,52,62]; it apparently does not do well in extremely wet conditions [12,17,30,52]. At Stones River National Battlefield, wintercreeper occurs on flat to gently sloping, rocky upland woods on soils derived from limestones or other basic substrates [49]. In Rock Creek Park in Washington, DC, wintercreeper occurs on low-fertility, fine-textured soils with pH ranging from 3.6 to 5.5 [20]. Wintercreeper occurred on sandy beach berms on the Potomac River lowland that were "occasionally overwhelmed by high tide" [59].

SUCCESSIONAL STATUS:
As of this writing (2009), very little information was available regarding successional relationships of wintercreeper. Some authors suggest that it can establish in relatively undisturbed habitats (e.g., [12,30]), and others suggest that populations of wintercreeper may establish in forest openings caused by windthrow, insect defoliation, or fire [1,30,52,62]. Records of field observations to support these suggestions were lacking in the available literature. A field study of old-growth forests in central Indiana, which were mostly small woodlots surrounded by agricultural fields, found that wintercreeper was at least as frequent in the forest interior as on the forest edge [7].

Observations by Hutchison [29,30] in Illinois suggest that invasive populations of wintercreeper may alter successional trajectories because it spreads rapidly and replaces spring ephemerals. In mesic and dry-mesic woods at Fern Rocks Nature Preserve, wintercreeper covered the ground and eliminated native groundcover species in many places [29]. Observations by managers in Kentucky indicate that invasive, groundcover populations of wintercreeper can establish monocultures in which native species are excluded (personal communication [38]).

Shade tolerance: Several reviews suggest that wintercreeper tolerates heavy shade [1,12,17,30,52], and a few of these also suggest that it also tolerates full sun [12,17,30,52]; empirical evidence of wintercreeper's shade tolerance is limited and somewhat contradictory. Shade tolerance may vary among cultivars. In a nursery experiment, the cultivar 'Variegata' was grown indoors in containers for 5 months under 1 of 3 conditions: 1) full sun, 2) 47% shade, 3) 64% shade. Growth indices (height + width + width/3, in cm) were significantly different (P=0.05) among treatments, with growth in full sun the lowest and in 47% shade the highest. Indices were 21.0, 25.0, and 22.9, respectively [34]. A nursery study in northwestern Arkansas using the cultivar 'Coloratus' reported that after fertilizer treatments and 6 months of growth, wintercreeper canopy cover was similar and total shoot dry weight was somewhat higher in full sun

than in 60% shade. After an additional fertilizer treatment and 6 months of additional growth, shoot and whole plant dry weights for wintercreeper were greater under full sun than 60% shade. Statistical comparisons were not made due to lack of replication [58].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Euonymus fortunei

FIRE EFFECTS:

Immediate fire effect on plant: As of this writing (2009) no information was available in the published literature regarding the immediate effects of fire on wintercreeper. Observations by managers indicate that wintercreeper does not burn easily and is not likely to be killed by fire of any severity (personal communications [38,63]). When it does burn, wintercreeper is only top-killed and sprouts from roots after burning (see Fire adaptations and plant response to fire). Even holding a propane torch in one place for long periods did not kill wintercreeper roots; plants were only top-killed and later sprouted (personal communication [38]).

No information was available regarding fire or heat effects on wintercreeper seed.

Postfire regeneration strategy [60]:
Small shrub, adventitious buds and/or a sprouting root crown
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources)

Fire adaptations and plant response to fire: As of this writing (2009), no information was available in the published literature regarding wintercreeper's fire adaptations or response to fire. Several sources suggest that wintercreeper sprouts from roots and root crowns when aboveground vegetation is physically removed (personal communications [38,63], reviews by [1,30,52,54]). Lempke (personal communication [38]) notes that wintercreeper is difficult to burn because its leaves have a thick cuticle. When it does burn, observations indicate that wintercreeper likely persists by sprouting from the roots and root crown (personal communications [38,63]), even after repeated burning treatments (personal communication [38]). Wintercreeper sprouted within about 45 days after plots with 100% wintercreeper cover were burned with a propane torch in late March 2003. Plots were burned again when wintercreeper reached 30% to 50% cover, and were repeatedly burned throughout the growing season (March through October) for a total of 7 treatments. The following year these plots were burned 5 times during the growing season. These treatments were discontinued, and in 2009, wintercreeper covered about 96% of the soil surface, with grasses and sedges composing 2% cover and woody seedlings composing 2% cover (personal communication [38]).

Wintercreeper may establish from seeds dispersed onto burns by animals after fire (see Seed dispersal).

FUELS AND FIRE REGIMES:

Fuels: Wintercreeper leaves have a thick cuticle, so it is difficult to get the moisture content low enough to burn. Using a 500,000 BTU propane torch it took approximately 35 to 40 minutes to burn 100 square feet of wintercreeper at 100% cover. Wintercreeper can carry fire in areas where bur oak (*Quercus macrocarpa*) leaves have accumulated on top of the wintercreeper. Patches of wintercreeper where leaves have been scorched with a propane torch and allowed to desiccate in warm, dry weather for 3 days may also carry fire (personal communication [38]).

Fire regimes: As of 2009, no information was available regarding fire regimes where wintercreeper is native. In North America, wintercreeper typically occurs in forests where presettlement fire regimes probably varied. For

example, it occurs in oak forests that likely experienced relatively frequent, low-severity fires; and it occurs in mixed mesophytic and northern hardwood forests that probably burned less frequently but with greater severity (reviews by [15,74]). Once established, wintercreeper is likely to survive and persist under any of these fire regimes (see Fire adaptations and plant response to fire). See the Fire Regime Table for summaries of fire regime characteristics for vegetation communities in which wintercreeper may occur.

Wintercreeper may alter fuel properties in invaded areas; however, no data are available on this topic. In areas where wintercreeper replaces plants with similar fuel properties, it may alter overall fuel biomass, which has the potential to influence fire intensity. In invaded areas where wintercreeper introduces novel fuel characteristics to the invaded system, it may have the potential to alter both fire intensity and fire frequency (*sensu* [13]). Several reviews (e.g., [5,6,14]) discuss effects of nonnative species invasions on fire regimes.

FIRE MANAGEMENT CONSIDERATIONS:

Preventing postfire establishment and spread: If fire occurs in an area where wintercreeper is already established, it is likely to survive and sprout after fire. If fire occurs in an area where wintercreeper does not occur on site, but flowering populations are known to occur in the vicinity, the site should be monitored for wintercreeper establishment, because seeds are readily spread by birds and other animals (see Seed dispersal). Wintercreeper seedlings should be removed immediately upon detection.

During fire suppression and postfire management activities in areas where wintercreeper occurs, preventing its establishment and further spread may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of wintercreeper plant material or seed into burned areas. General recommendations for preventing establishment and spread of invasive plants in burn areas include:

- Incorporate cost of weed prevention and management into fire rehabilitation plans
- Acquire restoration funding
- Include weed prevention education in fire training
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities
- Minimize the use of retardants 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 infestations within or adjacent to the burned area
- Reestablish desirable vegetation on bare ground as soon as possible
- Avoid use of fertilizers in postfire rehabilitation and restoration
- Use only certified weed-free seed mixes when revegetation is necessary

For more detailed information on these topics see the following publications: [4,23,68].

Use of prescribed fire as a control agent: In areas where wintercreeper has become a major component of the ground cover, prescribed fire is not likely to carry in the dense wintercreeper fuels, and is unlikely to control wintercreeper unless used in combination with other treatments (personal communications [38,63]). See Integrated management for details of a management approach that includes burning of wintercreeper using a propane torch.

In some forest ecosystems in which wintercreeper occurs, fire is either unlikely to burn (personal communication [9]) or is not desirable (review by [29]) due to potential negative impacts on native species.

MANAGEMENT CONSIDERATIONS

SPECIES: Euonymus fortunei

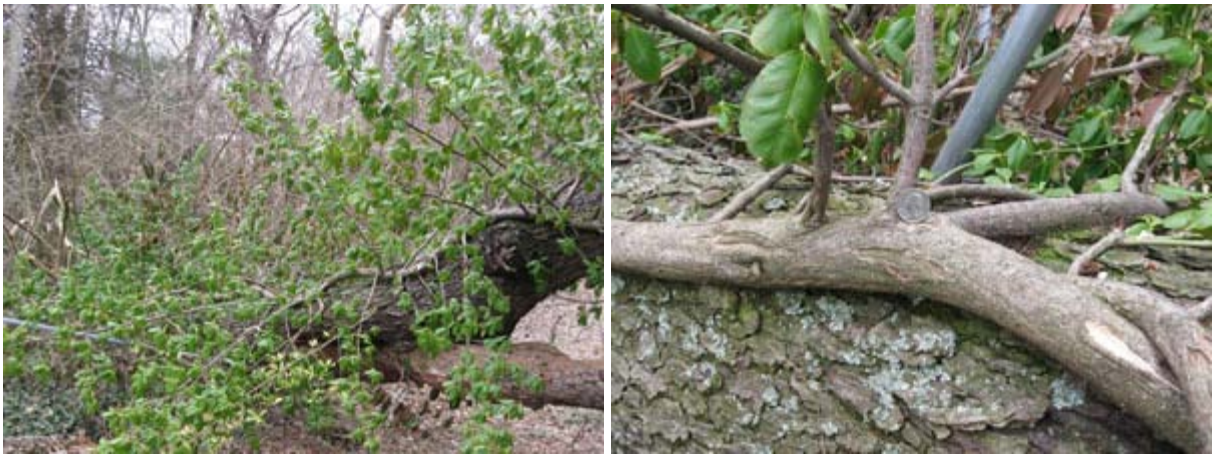
IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Wintercreeper was the most heavily browsed of more than 50 ornamental plant species studied during the winters of 1982 to 1984 at the Greenwich Landscaping Company in Connecticut. An average of 97.3% of wintercreeper shoots were browsed, substantially more than the congeneric, deciduous shrub winged burning bush (*E. alatus*) (10% browsed), another nonnative invasive plant [11]. 'Coloratus' plants in a nursery in northwestern Arkansas were damaged by rabbits in fall and winter, presumably because the rabbits were eating it [58].

Palatability/nutritional value: No information is available on this topic.

Cover value: No information is available on this topic.

OTHER USES:
No information is available on this topic.

IMPACTS AND CONTROL:
Impacts: As of this writing (2009), no studies were found in the available literature on the impacts of wintercreeper invasion; however, several reviews [12,29,35,52,54,62,64,67] and personal communications [9,38,63] indicate that wintercreeper is persistent,competitive, and difficult to control in some areas. A review by Remaley [52] suggests that the traits that make it a desirable ornamental plant, such as rapid growth, evergreen nature, and tolerance of variable site conditions, also make it a threat to natural areas. Reviews suggest that wintercreeper outcompetes and displaces native groundlayer plants (e.g., [12,52,62]) and may form single-species stands (review by [54]). Decreased native plant diversity may negatively impact native fauna (e.g., butterflies) [54]. Based on observations in Illinois, Hutchison [29] states that wintercreeper is a serious potential threat because it spreads rapidly and replaces spring ephemerals. In mesic and dry-mesic woods at Fern Rocks Nature Preserve, wintercreeper covered the ground and eliminated native groundcover species in many places [29]. Reviews suggest that wintercreeper may overtop and block sunlight to trees [12,52], possibly smothering and killing them [54], especially smaller trees (up to about 20 feet (6 m) tall) (personal communication [63]).



Wintercreeper liana in an ice-felled black cherry (*Prunus serotina*), approximately 40 feet (12 m) from the root collar. Photos, courtesy of David Taylor, taken 6 March 2009.

Rankings by the USDA, Forest Service [66,67], local exotic pest plant councils [21,35,45,57,64], and the Virginia Department of Conservation and Recreation [72] suggest that as of 2009, wintercreeper may be most invasive and have the greatest impact in the Southern Region, especially in Kentucky, Tennessee, and Missouri:

Invasiveness rankings by state and region in order of threat level		
Area	Rank	Rank definition
States		
Kentucky	Severe threat	Nonnative plant species that possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation. Includes species which are or could become widespread in Kentucky [35]
Tennessee	Rank 1, severe threat	Nonnative plant species that possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation [64].
Missouri	Category A-2	Plant species that are invading and disrupting native plant communities in more than 10 counties in Missouri [45]
Virginia	Moderately invasive	Nonnative plants that may have minor influence on ecosystem processes, alter plant community composition, and affect community structure in at least one layer. They may become dominant in the understory layer without threatening all species found in the community. Usually require a minor disturbance to establish [72]
South Carolina	Watch A	Nonnative plants found in South Carolina in limited infestations that are a potential threat to natural areas. They exhibit invasive characteristics such as high reproductive rate, high growth rate, and independent establishment of new populations [57].
Georgia	Category 3	Plants that are a minor problem in Georgia, or not yet known to be a problem in Georgia, but known to be a problem in adjacent states [21].
Regions		
Forest Service, Southern Region	Category 1	Nonnative plant species that are prohibited and must be controlled. These species are known to be invasive and persistent throughout all or most of their range within the Southern Region. They can spread into and persist in native plant communities and displace native plant species and therefore pose a demonstrable threat to the integrity of the natural plant communities in the region. Their use is prohibited on National Forest lands. Efforts to control these species are encouraged [67].
Forest Service, Eastern Region	Category 2	These plants are less invasive than those in Category 1. If these species are significantly replacing native species, they are doing so only in local areas [66].

Control: Probably the most effective way to control wintercreeper is to prevent its establishment by minimizing its use as a landscape plant and preventing further seed dispersal (see Prevention). Once established, control of wintercreeper requires complete removal of plants and roots, because it can spread vegetatively (see Vegetative regeneration). According to Hutchison [30], the most effective management of wintercreeper is to totally eradicate it from natural areas and the surrounding vicinity by pulling and removing individuals as soon as possible after recognition.

Fire: For information on the use of prescribed fire to control this species see Fire Management Considerations.

Prevention: It is commonly argued that the most cost-efficient and effective method of managing invasive species is

to prevent their establishment and spread by maintaining "healthy" natural communities [41,55] and by conducting monitoring several times each year [31]. Managing to maintain the integrity of the native plant community and to mitigate the factors enhancing ecosystem invasibility is likely to be more effective than managing solely to control the invader [28].

Weed prevention and control can be incorporated into many types of management plans, including those for logging and site preparation, grazing allotments, recreation management, research projects, road building and maintenance, and fire management [68]. See the Guide to noxious weed prevention practices for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

The simplest way to prevent wintercreeper establishment is to not plant it. Wintercreeper is commonly sold as a groundcover for landscaping [12]. Native creeping or climbing vines that may make good alternatives to wintercreeper in the eastern United States include trumpet creeper (*Campsis radicans*), Dutchman's pipe (*Aristolochia macrophylla*), crossvine (*Bignonia capreolata*), trumpet honeysuckle (*Lonicera sempervirens*), American bittersweet (*Celastrus scandens*), and American wisteria (*Wisteria frutescens*) [52,62]. If bittersweet and wisteria are used, make sure they are native species, as nonnative species in these genera (*C. orbiculatus*, *W. floribunda*, and *W. sinensis*) are also invasive.

Prevention of fruiting is critical to prevent further spread of wintercreeper once it is established. This is accomplished by cutting climbing stems to prevent flowering and fruiting (see Flowering and seed production), and repeating cutting to keep stems from climbing again (personal communication [63]).

Cultural control: According to Hutchison [29], no native species are known that can compete with wintercreeper in Illinois. However, planting competitive, desirable native species may help suppress wintercreeper as part of an integrated management plan (personal communication [38]).

Physical or mechanical control: Hand-pulling or grubbing using a pulaski or similar digging tool may control small populations of wintercreeper (reviews by [1,52]). In order to be effective, the entire plant, including the roots, stem fragments, and fruits, must be bagged and removed from the site to prevent reestablishment. Any portion of the remaining root system may sprout (reviews by [1,30,52,54]). Young plants with small root systems are likely easiest to control in this manner. Hand-pulling is easiest when soils are moist (reviews by [1,52]). Hand-pulling may be impractical for large infestations (review by [29]).

Cutting is not recommended as a control method except to prevent fruiting (personal communication [63], reviews by [43,54]) or in combination with herbicide application (see Chemical control). Cutting alone may lead to sprouting from roots, root crowns, and cut stems (personal communications [38,63], review by [52]). Mowing is similarly ineffective without chemical treatment and not practical in natural areas (review by [29]).

In an area of Kentucky where wintercreeper grew in monoculture (no native plants were visible), it was effectively suppressed when light was excluded by covering the population with 6 mil black plastic for an entire growing season (personal communication [38]); however, wintercreeper may require 2 years of covering to die (personal communication [9]).

Biological control: Biological control of invasive species has a long history that indicates many factors must be considered before using biological controls. Refer to these sources: [71,75] and the Weed control methods handbook [65] for background information and important considerations for developing and implementing biological control programs.

As of this writing (2009), no effective biological controls were known for wintercreeper. However, wintercreeper is one of the top 10 invasive plants of Asian origin in the United States that is being studied for future biological control opportunities, and scientists are looking for host-specific natural enemies in China [16]. Dirr [17] lists several diseases and insects that impact wintercreeper in North America. It is especially susceptible to damage and mortality from the Asian euonymus scale (*Unaspis euonymi*), which is not native to but does occur in North America [70]. The euonymus scale has been lethal to wintercreeper on many plantings, especially those containing the cultivars 'Vegetus',

'Coloratus', and *Euonymus* tree species such as European spindletree (*E. europaeus*), winterberry euonymus (*E. bungeanus*), and Hamilton's spindletree (*E. hamiltonianus* subsp. *sieboldianus*) (review by [17]). This same scale is also showing up on native *Euonymus* species, burningbush (*E. atropurpurea*) and bursting-heart (*E. americanus*), and it is causing mortality in populations of Canby's mountain-lover (*Paxistima canbyi*), a rare subshrub, in Kentucky (personal communication [63]). At least 5 organisms (2 insect predators and 3 aphelinid parasitoids) have been collected in Asia and released in southern New England as biological control agents against the euonymus scale. Releases were made in Massachusetts, Connecticut, and Rhode Island on wintercreeper and European spindletree plants infested with medium to large populations of euonymus scale in urban and suburban locations from 1991 to 1995 [70].

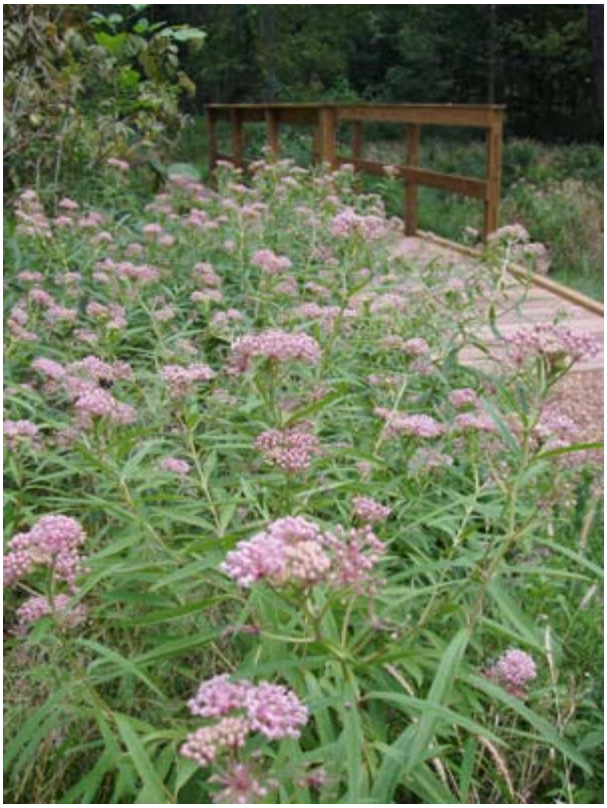
Intense seasonal browsing with domestic goats and/or sheep is being investigated as a potential control for wintercreeper in Kentucky. This approach shows some promise because wintercreeper is reportedly a frequent favorite for most livestock under the right conditions, and it is much browsed by white-tailed deer in the winter (personal communication [9]).

Chemical control: On wintercreeper populations that are too large to control by hand-pulling or digging, foliar or cut-stem applications of herbicides may be effective (reviews by [1,12,30,52,54]). Cut stem application of herbicides is effective in areas where lianas are well established on or around nontarget plants or where they have grown into tree canopies or other vertical surfaces. Subsequent foliar application of herbicides will likely be required for adequate control [1,52]. Foliar applications of herbicide may be used to control large populations of wintercreeper. It may be necessary to precede foliar sprays with cut stem treatments to reduce the risk of damage to nontarget plants [1,52]. Whichever method is used, multiple herbicide treatments are needed to control wintercreeper (personal communications [38,63]) because it sprouts following top-kill.

Recommended timing of herbicide treatment for wintercreeper is late fall, when most native vegetation is dormant, or in spring prior to emergence of spring ephemerals (reviews by [12,30]). Herbicide use is not recommended during the growing season, when native species are likely to be impacted. Care should be taken to avoid contacting nontarget species with herbicide (review by [30]).

Herbicides may be effective in gaining initial control of a new invasion or a severe infestation, but they are rarely a complete or long-term solution to weed management [8]. See the Weed control methods handbook [65] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals. See these sources: [1,43,52] for details on specific chemicals, timing, rates, and methods used for controlling wintercreeper.

Integrated management:
Intensive management of wintercreeper monocultures, integrating burning with a propane torch and/or spot spraying with glyphosate followed by planting of desirable species, may effectively suppress wintercreeper and promote desirable plant communities. Monocultures in Kentucky were sprayed with glyphosate in spring, when there were about 6 newly-formed leaves without a thick cuticle. Leaves turned red and dropped off in the fall. Any new wintercreeper sprouts that emerged the following spring were spot sprayed with glyphosate, and where the native seed bank was slow to respond, wild rye (*Elymus villosus* and *E. macgregori*) was seeded. Areas with dense wild rye stands had no rebound of wintercreeper populations (personal communication [38]).



An intensively managed swale that was once 100% wintercreeper. Treatments were: burning with propane torch, followed by spot spraying of glyphosate and hand pulling of sprouts the 1st year; and planting swamp milkweed (*Asclepias incarnata*), wild rye and fowl manna grass (*Glyceria striata*) plugs the 2nd year. Photo taken in year 3 (personal communication [38]).
Photo courtesy of Jim Lempke, University of Kentucky Arboretum

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APPENDIX: FIRE REGIME TABLE

SPECIES: Euonymus fortunei

This Fire Regime Table summarizes characteristics of fire regimes for vegetation communities in which wintercreeper may occur based on descriptions in available literature. Follow the links in the table to documents that provide more detailed information on these fire regimes. This table may not include every plant community in which wintercreeper occurs. For information on other plant communities, see the complete FEIS Fire Regime Table.

Fire regime information on vegetation communities in which wintercreeper may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [37], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Northern Great Plains	Great Lakes	Northeast
South-central US	Southern Appalachians	Southeast

Northern Great Plains

- Northern Plains Grassland
- Northern Plains Woodland

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northern Plains Grassland					
Oak savanna	Replacement	7%	44		
	Mixed	17%	18		
	Surface or low	76%	4		
Northern Plains Woodland					
Oak woodland	Replacement	2%	450		
	Surface or low	98%	7.5		

Great Lakes

- Great Lakes Grassland
- Great Lakes Woodland
- Great Lakes Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Great Lakes Grassland					
Mosaic of bluestem prairie and oak-hickory	Replacement	79%	5	1	8
	Mixed	2%	260		
	Surface or low	20%	2		33
Great Lakes Woodland					
Northern oak savanna	Replacement	4%	110	50	500
	Mixed	9%	50	15	150
	Surface or low	87%	5	1	20
Great Lakes Forested					
Northern hardwood maple-beech-eastern hemlock	Replacement	60%	>1,000		
	Mixed	40%	>1,000		
	Mixed	7%	833		

Great Lakes floodplain forest	Surface or low	93%	61		
Maple-basswood	Replacement	33%	≥1,000		
	Surface or low	67%	500		
Maple-basswood mesic hardwood forest (Great Lakes)	Replacement	100%	>1,000	≥1,000	>1,000
Maple-basswood-oak-aspen	Replacement	4%	769		
	Mixed	7%	476		
	Surface or low	89%	35		
Northern hardwood-eastern hemlock forest (Great Lakes)	Replacement	99%	>1,000		
Oak-hickory	Replacement	13%	66	1	
	Mixed	11%	77	5	
	Surface or low	76%	11	2	25
Pine-oak	Replacement	19%	357		
	Surface or low	81%	85		
Northeast • Northeast Grassland • Northeast Woodland • Northeast Forested					
Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northeast Grassland					
Northern coastal marsh	Replacement	97%	7	2	50
	Mixed	3%	265	20	
Northeast Woodland					
Eastern woodland mosaic	Replacement	2%	200	100	300
	Mixed	9%	40	20	60
	Surface or low	89%	4	1	7
Oak-pine (eastern dry-xeric)	Replacement	4%	185		
	Mixed	7%	110		

	Surface or low	90%	8		
Northeast Forested					
Northern hardwoods (Northeast)	Replacement	39%	≥1,000		
	Mixed	61%	650		
Eastern white pine-northern hardwoods	Replacement	72%	475		
	Surface or low	28%	>1,000		
Northern hardwoods-eastern hemlock	Replacement	50%	≥1,000		
	Surface or low	50%	≥1,000		
Northern hardwoods-spruce	Replacement	100%	≥1,000	400	>1,000
Appalachian oak forest (dry-mesic)	Replacement	2%	625	500	≥1,000
	Mixed	6%	250	200	500
	Surface or low	92%	15	7	26
Beech-maple	Replacement	100%	>1,000		
South-central US • South-central US Grassland • South-central US Woodland • South-central US Forested					
Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
South-central US Grassland					
Oak savanna	Replacement	3%	100	5	110
	Mixed	5%	60	5	250
	Surface or low	93%	3	1	4
South-central US Woodland					
Interior Highlands dry oak/bluestem woodland and glade	Replacement	16%	25	10	100
	Mixed	4%	100	10	
	Surface or low	80%	5	2	7
South-central US Forested					

Interior Highlands dry-mesic forest and woodland	Replacement	7%	250	50	300
	Mixed	18%	90	20	150
	Surface or low	75%	22	5	35
Southern floodplain	Replacement	42%	140		
	Surface or low	58%	100		
Southern floodplain (rare fire)	Replacement	42%	≥1,000		
	Surface or low	58%	714		

Southern Appalachians

- Southern Appalachians Grassland
- Southern Appalachians Woodland
- Southern Appalachians Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southern Appalachians Grassland					
Bluestem-oak barrens	Replacement	46%	15		
	Mixed	10%	69		
	Surface or low	44%	16		
Eastern prairie-woodland mosaic	Replacement	50%	10		
	Mixed	1%	900		
	Surface or low	50%	10		
Southern Appalachians Woodland					
Oak-ash woodland	Replacement	23%	119		
	Mixed	28%	95		
	Surface or low	49%	55		
Southern Appalachians Forested					
Bottomland hardwood forest	Replacement	25%	435	200	≥1,000
	Mixed	24%	455	150	500
	Surface or low	51%	210	50	250
Mixed mesophytic hardwood	Replacement	11%	665		
	Mixed	10%	715		

	Surface or low	79%	90		
Appalachian oak-hickory-pine	Replacement	3%	180	30	500
	Mixed	8%	65	15	150
	Surface or low	89%	6	3	10
Eastern hemlock-eastern white pine-hardwood	Replacement	17%	≥1,000	500	>1,000
	Surface or low	83%	210	100	>1,000
Appalachian oak forest (dry-mesic)	Replacement	6%	220		
	Mixed	15%	90		
	Surface or low	79%	17		

Southeast

- Southeast Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southeast Forested					
Coastal Plain pine-oak-hickory	Replacement	4%	200		
	Mixed	7%	100		
	Surface or low	89%	8		
Southern floodplain	Replacement	7%	900		
	Surface or low	93%	63		

*Fire Severity Definitions:
Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [25,36].

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