Populus alba and hybrids

INTRODUCTORY

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FEIS ABBREVIATION:
POPSPP
POPALB
POPCAE
POPHEI
POPROU
POPTOM

NRCS PLANT CODE [114]:
POAL7
POCA14
POHE5

PORO4
POTO7

COMMON NAMES:
for *Populus alba*:
white poplar
European white poplar
silver poplar

for *Populus alba* hybrids:
gray poplar
Heimburger's poplar
Roulwau's poplar
Chinese white poplar

TAXONOMY:
The scientific name of white poplar is *Populus alba* L. (Salicaceae) [30,39,59,84,107,125]. White poplar is part of the aspen and white poplar group or the *Populus* section of the genus *Populus* [17].

Hybrids:
Populus × *canescens* (Aiton) Sm. (gray poplar), a cross between *P. alba* × *P. tremula* (European aspen)
Populus × *heimburgeri* B. Boivin (Heimburger's poplar), a cross between *P. alba* × *P. tremuloides* (quaking aspen)
Populus × *rouleauiana* B. Boivin (Roulwau's poplar), a cross between *P. alba* × *P. grandidentata* (bigtooth aspen) ([39], Boivin 1966 cited in [102])
Populus × *tomentosa* Carrière (Chinese white poplar), a cross between *P. alba* × *P. adenopoda* (Chinese aspen) [30]

White poplar hybrids with European aspen, quaking aspen, and bigtooth aspen occur primarily east of the Great Plains region of North America [39]. However, hybrids are possible in any area where the parent species' distributions overlap. Hybridization has the potential to affect white poplar invasiveness. This is discussed later in the seed production, dispersal, vegetative spread, and potential impacts sections. *Populus alba* × *P. adenopoda* hybrids have been planted in the southeastern United States, although rarely [30].

White poplar hybrids are identified using scientific parent names in this review.

SYNONYMS:
for *Populus alba* L.:
Populus alba var. *bolleana* Lauche [122]
Populus alba var. *pyramidalis* Bunge [51,125]

for *Populus* × *canescens* Aiton (Sm.):
Populus alba L. var. *canescens* (Aiton) [25]

LIFE FORM:
Tree

DISTRIBUTION AND OCCURRENCE

SPECIES: Populus alba and hybrids

GENERAL DISTRIBUTION:
White poplar is nonnative to but has been widely planted in North America [68,88]. It is most widely escaped in the eastern United States and Canada [68]. White poplar populations are generally restricted to planting sites in the West [49,78] but have spread from planting sites in states and provinces east of the Great Plains [7,35,77,84,92]. White poplar's native range includes central, southern, and eastern Europe, the Mediterranean islands, temperate Asia, and northern Africa [34,120].

In North America, white poplar hybrids are known only east of the Great Plains. *Populus alba* × *P. tremula* is the most widely distributed hybrid; it occurs in nearly all states and provinces east of the north-south area from western Ontario to Louisiana [114]. Hybrids with native aspens (quaking aspen and bigtooth aspen) occur primarily in the Great Lakes region [101], although *P. alba* × *P. grandidentata* has been reported in West Virginia [114]. *Populus alba* × *P. tremuloides* is less widely distributed and less common than *P. alba* × *P. grandidentata* [100,114,119]. Plants Database provides distributional maps of white poplar and its hybrids.

White poplar was reported in New England by 1785 (Cutler 1785 cited in [102]), and after its introduction, planting was widespread. By the late 1800s, it was noted in many US floras. White poplar occurred in Michigan by 1876 (Almendinger 1876 cited in [102]), in southwestern Texas by 1879 (Watson 1883 cited in [102]), and on Block Island, Rhode Island, by 1892 [4]. In North Dakota and Montana, it was planted by ranchers and farmers for windbreaks [111].

Because white poplar spread is generally limited to clonal growth in the absence of hybridization (see Seed production), the distribution and spread of white poplar is directly related to human plantings [100]. Widespread planting has given white poplar a wider distribution than native aspens in the United States (Barnes personal communication cited in [102]). In northern Cape Breton, Nova Scotia, white poplar is largely restricted to areas where it was planted as an ornamental. It persists through vegetative sprouting [103]. In Farmington, western Maine, the spread of escaped white poplars was easily traced back to areas where white poplar was planted [6]. Throughout the Georgia Piedmont, the distribution of white poplar was directly correlated with the relative number of residences [23]. The composition of the deciduous Black Rock Forest in southeastern New York was compared from 1930 to 2006. White poplar was first reported in the study area in the 1990s. Although researchers indicated that white poplar "invaded naturally", they did not speculate on the establishment method and failed to report the location of the nearest white poplar population [90].

HABITAT TYPES AND PLANT COMMUNITIES:
Nonnative habitats: In its North American range, white poplar occurs in open disturbed sites, grasslands, shrublands, early-seral forests, and floodplain woodlands [34,120]. In New England, it occurs along roadsides and in fields, meadows, wet shrublands, early-seral forests, and floodplain forests [73]. In a midseral old field on Howard University's Beltsville campus in Maryland, white poplar was codominant with red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) [83]. Along the Mississippi River in Hickman County, Kentucky, white poplar thickets occurred with eastern cottonwood (*P. deltoides* subsp. *deltoides*) and narrowleaf willow (*Salix exigua*) on sand deposited by flooding [41]. In the Midwest, large white poplar clones have reduced the abundance of shade-intolerant species in prairies and savannas [97]. In southeastern Michigan, white poplar and its native aspen hybrids occurred in early-seral communities dominated by poison sumac (*Toxicodendron vernix*), red-osier dogwood (*Cornus stolonifera* subsp. *stolonifera*), and gray dogwood (*C. racemosa*) on mesic sites and black oak (*Quercus velutina*), black cherry (*Prunus serotina*), and black locust (*Robinia pseudoacacia*) on dry sites [102]. Along the Missouri River in southeastern South Dakota, white poplar occurred in cottonwood (*Populus* spp.)-dominated floodplain forests [104].

Native habitats: In western and central Europe, white poplar occurs in riparian, forest-steppe, and coastal communities. Gravel bars and hardwood floodplain woodlands are common white poplar habitats [27,63,66,94]. In Hungary, white poplar occurs in forest-steppe vegetation characterized by sandy grasslands with patches of white poplar, Lombardy poplar (*P. nigra*), and common juniper (*Juniperus communis*) [79]. White poplar sometimes forms thickets on coastal cliffs in southeastern England [26].

Additional information about white poplar's nonnative and native habitats is available in Site Characteristics and Successional Status.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Populus alba and hybrids

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GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
- **Raunkiaer life form**

Botanical description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [39,60,84,107,122]).

White poplar is typically a small tree but may reach 130 feet (40 m) tall and 7 feet (2 m) in diameter [24,47,107]. The crown is open, wide, and rounded [18,47,105,122]. Low branches are reportedly very persistent [102]. Sometimes the white poplar trunk is divided at the base [39], and often it is crooked [102]. Bark is smooth on young trunks [39] but becomes rough on the lower portion of mature trunks [51]. White poplar is short-lived [13,18,117], and its wood is weak and prone to storm breakage [13].

White poplar leaves are alternate, glossy blue-green above, and white with dense hairs below [18,24,47,91,105]. Early leaves are nearly oval and have margins with rounded teeth [28]; mature leaves have 3 to 7 blunt lobes [35,91] with toothed to wavy margins [39,105]. Leaves measure 1 to 5 inches (3-12 cm) long and are longer than they are wide [71,122], but leaf morphology can be variable [117]. White poplar hybrids produced smaller leaves on dry sandy sites than on mesic or wet sites [102].

White poplar is dioecious. Most white poplars introduced to North America are female. Catkins are dense and support about 50 individual flowers [26]. Pistillate catkins measure 1.5 to 3 inches (4-7 cm) long; staminate catkins measure 2 to 4 inches (5-10 cm) long [105]. Because male white poplar trees are rare and generally not available to fertilize female trees, fruit and seed production are typically restricted to white poplar hybrids in North America [101]. White poplar fruits, although not typically produced outside of hybridization, are 3- to 5-mm capsules that typically contain 2 seeds [39,71]. White poplar seeds are tiny (up to 1.5 mm long) with long, fine hairs at the base [26,105].

Hybrids: White poplar hybrids are difficult to distinguish from parents in the field. Molecular markers are the best way to avoid misclassification of white poplar hybrids [31]. Descriptions of *P. alba* × *P. grandidentata* and *P. alba* × *P. tremuloides* hybrids are available in the following references: [5,30,102]. *Populus alba* × *P. adenopoda* is described in the Flora of North America [30].

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Belowground description: Researchers excavated and described the root system of white poplars growing on Rhinau Island in eastern France. Root density was greatest at 12- to 24-inch (30-60 cm) depths. At these depths, some roots were greater than 2 inches (5 cm) in diameter. Root abundance in the top 4 inches (10 cm) of soil increased with increasing distance from the trunk. Three feet (1 m) away from the trunk, white poplar roots reached the gravel layer, which was 43 inches (110 cm) deep. Excavation did not occur beyond the gravel layer [89].

White poplar is capable of prolific root sprouting, which allows for long-term persistence [13,18].

Raunkiaer [85] life form:
Phanerophyte
Geophyte

SEASONAL DEVELOPMENT:
In the United States, white poplar typically flowers in the spring (March-early June) [51,60,92,107]. Catkins appear before the leaves [39]. If fruits are produced, they appear in April, May, or June [39,105].

REGENERATION PROCESSES:
White poplar predominantly regenerates vegetatively. Because only female trees are generally present at a given location [24], sexual reproduction is usually limited to white poplar hybrids [101].

Vegetative regeneration: Vegetative regeneration and reproduction are vital to white poplar growth, spread, persistence, and recovery from injury [91,105]. Clonal growth and spread most commonly occur by root sprouting [60,119,122] but may also occur through fragmentation and layering [94]. Fragmentation describes the process by which new clones can develop from twig or root pieces that become partially buried in sand or silt ([94], review by [17]). Observations in South Africa led researchers to conclude that white poplar and *P. alba* × *P. tremula* were dispersed through the movement of vegetative parts in water [46].

White poplar root sprouts have been described as prolific [102], "vigorous" [73], and "objectionable" [68]. Dense colonies or thickets from root sprouts [60,119,122] can cover large areas [105]. When white poplar seedlings were grown and evaluated as shelterbelt trees in the northern Great Plains, root suckers were frequently reported long distances from the parent tree [33]. According to a review by Spies [102], vegetative sprouts can occur up to 160 feet (50 m) from the parent. In southeastern Michigan, the average size of individual *P. alba* × *P. grandidentata* or *P. alba* × *P. tremuloides* clones was 0.02 to 0.5 acre (0.01-0.2 ha). The average number of stems per clone ranged from 1 to 404. *Populus alba* × *P. grandidentata* sprouted more "vigorously" than bigtooth aspen or quaking aspen [102].

Surveys of white poplar stands on the Mediterranean island of Sardinia showed that most sites supported single-sex ramets from a single parent that in some cases, formed linear riparian stands extending several kilometers. Four monoclonal stands ranged from 38.6 mile² (100 km²) to over 1,500 mile² (4,000 km²). Fertile seed occurred in just 1 of 80 sampling sites, and no seedlings were observed at any site [10]. In lowland floodplain forests along the Danube in Austria and Slovakia, *P. alba* × *P. tremula* and white poplar clones extended over distances of 610 feet (186 m) and 430 feet (132 m), respectively. Researchers indicated that these were likely conservative clone size estimates, since trees were not exhaustively sampled [116].

Vegetative regeneration from root sprouts is important to white poplar persistence and recovery from injury. White poplar produces shoots from surviving roots long after the original parent tree has died [47,102,105]. In 1888, white poplar cuttings were planted at the Grayling Agricultural Experiment Station in Crawford County, Michigan. During visits to this planting site between 1998 and 2000, root sprouts from the original plantings were still present [62]. In Iowa, 2 studies from the 1950s reported that *P. alba* × *P. grandidentata* clones persisted and spread vegetatively from 2 or more seedlings that established in the early 1900s [67,72]. Sprouting is rapid and prolific following the death of white poplar trees or stems [73,84,105]. This regenerative potential, however, may decrease with tree age, according to a review of the *Populus* genus by Dickmann [17]. These studies and findings suggest that although white poplar is short-lived, once planted this species can permanently occupy its original planting site or a much larger area.

Studies indicate that white poplar may disperse and establish new populations from vegetative fragments [17,46], but most studies testing the regenerative capacity of white poplar involve experiments with somewhat artificial conditions. In a controlled study involving plant material from southeastern Canada, the vegetative regeneration potential of white poplar and *P. alba* × *P. grandidentata* appeared to be much greater than that of bigtooth aspen. About 90% of white poplar cuttings rooted and 65% to 98% of hybrid cuttings rooted, but only about 5% of bigtooth aspen cuttings rooted [56]. From *P. alba* × *P. grandidentata* plant material collected in southeastern Iowa, researchers found that root segments greater than 0.5 inch (1.3 cm) in diameter and 2 inches (5 cm) long often produced more than 1 sprout/root segment. When root segments were planted in unseasonably warm, dry weather, very few sprouted. However, some of the root segments sprouted the following growing season [42].

Pollination and breeding system: White poplar flowers are wind pollinated [18,116]. However, because male white poplar trees are rare, successful pollination of white poplar generally requires hybridization with European aspen, bigtooth aspen, or quaking aspen ([28,101], Schlenker 1953 cited in [29]). Hybridization and backcrossing between white poplar and native aspens could cause nonnative gene introgression into the native gene pool [102,103]. Studies in southeastern Michigan, however, did not find widespread backcrossing or gene flow between white poplar and bigtooth aspen [100].

Hybridization between white poplar and native and nonnative aspens may be affected by the phenology and location of parent populations. In southeastern Michigan, *P. alba* × *P. grandidentata* is much more common than *P. alba* × *P. tremuloides*, and nearly all hybrids occur to the east of white poplar clones. The easterly distribution of hybrids was expected because of prevailing western winds, but based on the distribution and abundance of parent species, researchers expected a 1:1 ratio of *P. alba* × *P. grandidentata* and *P. alba* × *P. tremuloides* hybrids. A single season of observations did not reveal a phenological barrier to hybridization between white poplar and quaking aspen. However, researchers noted that female receptivity is difficult to observe and suggested that the degree of phenological differences and overlap may have been missed in just one season of observations [101,102].

In its native habitats, *P. alba* × *P. tremula* backcrossed with white poplar more often than with European aspen. Along the Ticino River in northern Italy, *P. alba* × *P. tremula* backcrossed with white poplar but not with European aspen. Researchers suspected their findings were related to the distance to European aspen trees or other preferential backcrossing, although these factors were not investigated [31]. Similar findings were reported in the Danube Valley near Vienna, Austria. Most hybridization occurred between white poplar females and European aspen males, and most backcrossing occurred with white poplar. Because European aspen produced male flowers several weeks earlier than white poplar, European aspen may have fertilized white poplar before white poplar pollen was shed [66].

Seed production: Several floras report that white poplar fails to produce seed [13,18,25]. In North America, most planted white poplar were female [101]; however, in a survey of eastern herbia, 5 of 8 had male white poplar branches

in their collection [102]. In North America, most seed production by white poplar occurs through hybridization with bigtooth aspen, quaking aspen, or European aspen ([101], Schlenker 1953 cited in [29]). In southeastern Michigan, all white poplar clones surveyed were female. White poplar hybrids, however, were male, female, or hermaphroditic with separate staminate and pistillate catkins (review by [101], Schlenker 1953 cited in [29]).

Although white poplars generally become sexually mature at 5 to 7 years old (Braatne and others 1996 cited in [75]), one genotype grown from seed collected along the Italian peninsula flowered at 1 year old. Subsequent clones regenerated from this genotype failed to flower in their first year without at least 6 months of root chilling treatments [75].

White poplar hybrids can produce an abundance of viable seed. When white poplar and *P. alba* × *P. grandidentata* clones were pollinated openly in a greenhouse, white poplar averaged 23.9 seeds/shoot, and *P. alba* × *P. grandidentata* averaged 415.9 seeds/shoot [102]. All *P. alba* × *P. grandidentata*, *P. alba* × *P. alba* × *P. grandidentata*, *P. alba* × *P. grandidentata* × *P. tremula*, and *P. alba* × *P. grandidentata* × *P. alba* × *P. tremula* hybrids that were experimentally produced in Ottawa produced viable seed. Seed set was best from crosses between white poplar and bigtooth aspen [57].

Seed dispersal: White poplar and its hybrids produce light-weight, plumose, wind-dispersed seeds ([116], Graham and others 1963 cited in [102]). In the greenhouse, the average weight of seeds produced by 9 open-pollinated white poplar clones was 0.177 mg/seed, and the average weight of seeds produced by *P. alba* × *P. grandidentata* clones was 0.199 mg [102]. Although cottonwood (*Populus* spp.) seeds have been reported to disperse 19 miles (30 km) or more (van der Pijl 1972 cited in [101]), surveys in southeastern Michigan revealed that most (91%) white poplar hybrid seedlings occurred within 1 mile (1.6 km) of white poplar clones [101].

Seed banking: Although field experiments are lacking, white poplar and hybrid seeds are reportedly very short-lived (England Forestry Commission Booklet [26]). A review reports that seed bank longevity is low for Salicaceae [58].

Germination: The optimal conditions for germination of white poplar and hybrid seeds were not reported. A review reports that within Salicaceae, germination is rapid and often occurs within 24 hours of seed shed. Germination percentages are drastically reduced in dry conditions, but germination occurs in moist conditions, at warm temperatures (59-81 °F (15-27° C)), and in dark environments [58]. Soaking reduced the germination of white poplar seeds in the laboratory. Just 23.4% of dry seeds failed to germinate; up to 34.2% of soaked seeds failed to germinate. Nearly 65% of dry white poplar seeds germinated without abnormalities (poor substrate attachment and imperfect geotropism). After soaking 1 to 60 minutes, just 24% to 27% of germinated seedlings lacked abnormalities. Duration of soaking did not greatly affect germination [82]. The survival of abnormal seedlings was not reported, but it could be expected that survival of abnormal seedlings was less than that of normal seedlings.

Germination of white poplar hybrid seeds can be high. When white poplar and *P. alba* × *P. grandidentata* were openly pollinated in a greenhouse, germination of seeds collected from white poplar averaged 34.7%, and germination of seeds collected from *P. alba* × *P. grandidentata* averaged 81.8% [102]. All *P. alba* × *P. grandidentata*, *P. alba* × *P. alba* × *P. grandidentata*, *P. alba* × *P. grandidentata* × *P. tremula*, and *P. alba* × *P. grandidentata* × *P. alba* × *P. tremula* hybrids that were experimentally produced in Ottawa produced viable seed. Germination was best (61%) for seed produced by crosses between white poplar and bigtooth aspen. Germination of seed produced by the other crosses ranged from 21% to 40% [57].

Seedling establishment and plant growth: In the field, seedling recruitment is generally limited to white poplar hybrids. Information on nonhybrid white poplar seedling establishment is generally limited to studies conducted on trial plantings or in plantations. Establishment of white poplar and hybrid seedlings is likely best on sites with exposed mineral soil that lack other established vegetation.

Although nonhybridized white poplar seedlings are considered unlikely, researchers reported that white poplar "seedlings have been observed to freely colonize neighboring ruderal sands" on western Fire Island in Suffolk County, New York. Bigtooth aspen and quaking aspen were also reported on the island [22], suggesting that seedling recruitment may have been the result of hybridization between white poplar and native aspens. White poplar hybrids

can produce seedlings. Many hybrids and backcrosses were experimentally created between white poplar, bigtooth aspen, and quaking aspen. All hybrids produced seed, and seedling survival was at least 29% [57]. When 10-week-old, greenhouse-grown white poplar and *P. alba* × *P. grandidentata* seedlings were transplanted outdoors, about 70% of white poplar and 93% of hybrid seedlings survived to the end of the growing season [102].

Excessively dry conditions, harsh winters, and established vegetation may limit survival and growth of white poplar and hybrid seedlings. When white poplar seedlings from Xinjiang, China, were planted at the Northern Great Plains Field Station in Mandan, North Dakota, most failed to survive longer than 10 years. Only 1 seedling survived more than 10 years, and it did not survive 36 years. Dry conditions and winter injury were the most common causes of mortality [33].

In southeastern Michigan, open sites with exposed mineral soil were best for the establishment of white poplar hybrid seedlings. In the Walsh Lake study area in Washtenaw County, *P. alba* × *P. grandidentata* established during a 9-year period following agricultural abandonment. In Livingston County, *P. alba* × *P. grandidentata* and *P. alba* × *P. tremuloides* established at the edge of lakes, ponds, and swamps and on dry, disturbed sites. Both kinds of sites had experienced disturbances that exposed mineral soil. In both counties, hybrid seedling establishment decreased as old-field and floodplain succession progressed [101].

Plant growth: Rapid growth is characteristic of white poplar and its hybrids [70,102]. While hybrids may grow faster than parent species, differences in growth rate may vary by genotype, site, and/or clone age [55,56,86]. Discoveries of rapid tree growth and biomass production by white poplar hybrids in the Great Lakes contributed to increased recommendations for planting hybrids on plantations and in wildlands [40,43,43,72].

Rapid growth of white poplar and its hybrids has been recorded in their native and nonnative ranges. Along the Henares River floodplain in Madrid, Spain, white poplar clones almost doubled in size in 5 years. In 4-year-old plantations, white poplar averaged 2.8 inches (7.2 cm) in DBH and 16 feet (4.9 m) tall. In 9-year-old plantations, white poplar averaged 6.5 inches (16.5 cm) in DBH and 30 feet (9.2 m) tall [70]. In southeastern Michigan, *P. alba* × *P. grandidentata* clones that were 28 to 53 years old had annual height increases of 1.1 to 2.3 feet (0.3-0.7 m) and annual DBH increases of 0.2 to 0.4 inch (0.5-1 cm) [102].

In North America, white poplar hybrids are often larger than their parent species of the same age. However, this was not the case in Hungary, where white poplar and *P. alba* × *P. grandidentata* grown in a common area were nearly the same size at 3, 7, and 10 years old. Often the maximum DBH reported for white poplar clones exceeded that of hybrids [86]. In a common area in southeastern Canada, *P. alba* × *P. grandidentata* was larger than both parent species of the same age. At 5 years old, average stem height was 14 feet (4.3 m) for white poplar clones, 11.7 feet (3.6 m) for bigtooth aspen clones, and 17.6 feet (5.4 m) for *P. alba* × *P. grandidentata* clones [56]. The clonal growth capacity of white poplar hybrids and parent species are compared in the vegetative regeneration discussion above. In Quebec, *P. alba* × *P. grandidentata* and *P. alba* × *P. tremuloides* were typically larger than the parent species when trees were 13 to 19 years old. In young age classes (6-7 years old), hybrid size was much more variable than parent species' sizes, and the maximum height and DBH were generally largest for hybrid clones [55].

SITE CHARACTERISTICS:
Throughout its North American range, white poplar is most common near current or abandoned settlements where it was planted. It is often found in fields and along fence lines, ditch banks, and roads [7,12,47,51,60,71,105,122]. Disturbed areas near established white poplar stands are often colonized by root sprouts [39,92,119].

In southeastern Michigan, most white poplar hybrids were found around current or former farms. No hybrids occurred in forests considered relatively undisturbed by humans. Nearly half of the hybrids occurred on sparsely vegetated, dry, sandy sites. The other half occurred on mesic sites, often at the edges of lakes, ponds, and swamps [101].

Climate: White poplar occurs in areas as far north as USDA hardiness zone 3, where average annual minimum temperatures can reach -40 °F (4 °C) [19,28,68]. However, some report that white poplar may be killed or injured by extremely low winter temperatures [19,33], suggesting that white poplar may be restricted to protected sites in its northernmost habitats. In a review, Spies [102] reports that white poplar is most common at low elevations where

temperatures are moderate and moisture is favorable. Although white poplar commonly occupies moist habitats, it can also occupy upland, somewhat droughty habitats [17]. In Hungary, white polar occurs in semiarid forest-steppe vegetation that grows in a temperate continental climate with annual precipitation averaging 20 to 22 inches (500-550 mm) [79].

In growth chamber experiments, researchers found *P. alba* × *P. grandidentata* growth was best when soil moisture was 16% to 30% and temperatures were 77 to 95 °F (25-35 °C) during the day and 59 to 77 °F (15-25 °C) at night. The parameters necessary for interpreting soil moisture values in this study include a level of 8.6%—which was slightly above the permanent wilting point—and a field capacity level of 35.6%. Height and stem diameter growth peaked at 23% average soil moisture. Height and stem size were also high at 30% and 32% soil moisture but were low at 9% soil moisture [20].

Elevation: Ranges of elevations reported for white poplar habitats in the western half of the United States

State or region	Elevation range
California	1,970-5,900 feet (600-1,800 m) [47]
Nevada	4,500-6,500 feet (1,400-2,000 m) [60]
New Mexico	6,500-7,500 feet (2,000-2,300 m) [71]
Utah	4,500-6,500 feet (1,400-2,000 m) [122]
Intermountain West	3,600-8,000 feet (1,100-2,400 m) [51]

Soils: Although growth may be best in moist, deep loams [19], white poplar and its hybrids grow in a variety of soil types and textures [105,117]. In the Southwest, white poplar occurs on dry, well drained sites [117], and in Michigan, white poplar thickets are common in sandy soils [119]. In southeastern Michigan, most white polar and hybrid stands occurred on loamy sands, but soil textures ranged from pure sands to nearly pure loams. Soil pH was mostly neutral but ranged from 5 to 8 [102]. White poplar persisted for more than 100 years at the Grayling Agricultural Experiment Station in Crawford County, Michigan, where soil pH, nutrients, and water-holding capacity were low [62]. In its native forest-steppe habitats in Hungary, white poplar occurred on soils with a sand content of greater than 96% and silt and clay content of less than 2% [79]. In the Danube-Tisza region of Hungary, more than 70% of white poplar stands occurred on calcareous soils [86].

Soil moisture: Floodplain and upland sites provide habitat for white poplar [17,45], and although white poplar may survive episodes of both flooding and low precipitation, experiments suggest that growth is best in moist conditions. In his review, Dickmann [17] reports that on dry soils, *P. alba* × *P. tremula* grows better than white poplar.

Studies suggest that white poplar and hybrid growth is best in moist but not saturated soils. In a controlled study, *P. alba* × *P. grandidentata* stem height increased with increasing soil moisture levels up to 34%; stem height was lower at a 41% moisture level. A lack of root aeration may have affected hybrid growth at 41% soil moisture. In this study, permanent wilting of the hybrids occurred at 9% to 11%, and soil was near field capacity at 41%. [96]. However, when ranchers and farmers in North Dakota and Montana were surveyed, those who planted white poplar on sites with a shallow water table ranked its windbreak performance lower than those who planted it on sites with deeper water tables [111].

In the few studies available, white poplar exhibited greater flood tolerance in its native than nonnative habitats. Along the Upper Rhine in France, white poplar occurs in a hardwood floodplain forest that is flooded almost every summer (June-August) [94]. When white poplar trees were planted around a reservoir in Davis, California, nearly 80% of white poplar trees survived 61 to 69 days of flooding in 2 consecutive years. Survival was much lower, 20%, after 100 days of flooding in 2 consecutive years. The age of white poplar trees at the time of flooding was not reported [45], but provided photos suggest the trees were less than 10 years old.

Salinity: White poplar tolerates salt spray [19] and grows in saline soils [17]. Some indicate that white poplar can establish and grow in soil with salinity levels of up to 4,000 mg/L (Wong and others 1985 as cited in [52]). In the Camargue in southern France, white poplar occurred in habitats where the soil salinity at 12 inches (30 cm) deep was up to 3,200 mg/L [76]. In a greenhouse experiment, the survival of 1-year-old white poplar seedlings was compared after adding various amounts of sodium to the soil. Growth of white poplar was significantly lower in high-salt than low-salt treatments (P=0.0183). After a year, all seedlings had survived the low-salt treatment, and mortality in the high-salt treatment was only 20% [52]. *Populus alba* × *P. tremula* is considered more tolerant of saline soils than white poplar [17], but comparisons between white poplar and its hybrids with aspens native to North America were not found.

SUCCESSIONAL STATUS:
White poplar is commonly associated with disturbed sites in both its native and nonnative ranges. In North America, it occurs in open sites [16,19] and old fields [83], as well as on floodplains [41], which are white poplar's most common habitat in Europe ([63], Lazowski cited in [66]). In its nonnative range, white poplar's presence in any habitat is dependent on prior plantings. Occurrence of white poplar hybrids depends on the presence of European aspen, quaking aspen, or bigtooth aspen. For clarification, see the Seed production, Seed dispersal, and Seedling establishment sections.

Studies suggest that shading does not substantially affect white poplar establishment and survival. Ordination analysis of hardwood floodplain forests along the Upper Rhine River in France showed that white poplar was associated with some of the most shaded plots [94]. During field studies in southeastern Iowa, researchers found that low survival and growth of *P. alba* × *P. grandidentata* cuttings were not related to light intensity when cuttings received 33% or more of full sun [32].

In its native and nonnative habitats, white poplar is common in early- to midseral communities. Along the Eygues River in France, it is one of the earliest colonizers of gravel bars left by formerly active channels [63]. White poplar and *P. alba* × *P. tremula* occur in lowland floodplain forests in Austria's Danube Valley. White poplar and the hybrid are closely associated with disturbed floodplains (Lazowski cited in [66]). In Hickman County, Kentucky, white poplar thickets developed in the initial stages of secondary succession after 43 feet (13 m) of sand was deposited by flooding of the Mississippi River [41]. In Wisconsin, white poplar occurs in early-successional dune communities, although severe tree damage from windblown sand was noted [15]. In southeastern Michigan, white poplar and its hybrids with native aspens occurred in early-seral communities on disturbed sites [102]. In an old field at Howard University's Beltsville campus in Maryland, white poplar was codominant in a midseral community with red maple and sweetgum [83].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Populus alba and hybrids

FIRE EFFECTS:
Immediate fire effect on plant: Even the most severe fires probably result only in top-kill of white poplar ([79], Johnson 2010 personal communication [54]).

Postfire regeneration strategy [106]:
Tree with adventitious buds, a sprouting root crown, sobols, and/or root suckers

Fire adaptations and plant response to fire: As of 2010, very few studies had examined the effects of fire on white poplar. Observations indicate that white poplar sprouted after a fire in forest-steppe vegetation in Hungary [79].

However, details regarding fire season, fire severity, postfire sprout abundance, and postfire sprout survival were lacking. North American studies of white poplar and fire were lacking as of the writing of this review (2010). The supervisory forester for Great Smoky Mountains National Park, Kristine Johnson, suggests that white poplar's prolific and persistent root system would survive and produce sprouts after even severe fire. Based on experiences from prior control attempts, Johnson predicts that white poplar sprouts would be abundant following fire and that repeated fire at short intervals would be necessary to kill white poplar clones (2010 personal communication [54]).

Seedling establishment on burned sites would likely be limited to white poplar hybrids. Thus, seedling establishment is probably limited to areas supporting white poplar together with bigtooth aspen, quaking aspen, and/or European aspen. In southeastern Michigan, sites with exposed mineral soil and limited vegetation cover were colonized by *P. alba* × *P. grandidentata* and *P. alba* × *P. tremuloides* seedlings [101], suggesting that burned sites may be favorable for white poplar hybrid seedling establishment. For more information on white poplar hybridization as it relates to Seed production, Seed dispersal, and Seedling establishment, follow the links to these earlier sections.

Without additional fire studies, it is impossible to address the long-term survival of white poplar postfire sprouts. However, a postdisturbance study following a major windstorm in a northern pin oak (*Q. ellipsoidalis*)-dominated woodland on Minnesota's Anoka Sand Plain suggests delayed mortality is possible following top-kill of white poplar. Just months after the storm, the frequency of white poplar was 28%. In the next 2 years, white poplar frequency was relatively unchanged. However, white poplar did not occur on study plots 7, 10, and 14 years after the windstorm [81]. Although this study did not involve fire, the environment after the windstorm is in some ways comparable to a postfire environment.

FUELS AND FIRE REGIMES:

Fuels: The information available on white poplar fuel characteristics describes both low flammability and increased woody fuel loads. Flammability of white poplar was reported as low in a Virginia Cooperative Extension publication [1]. White poplar was recommended for use in firebreaks in parts of Australia because of its firm bark, dense, compact crown, and low levels of volatile oils in foliage [95]. However, white poplar wood is weak and prone to breakage [13]. Twigs and limbs are dropped throughout the year [34]. Weak wood suggests that groundlayer woody fuel loads may be high in dense white poplar stands.

Fire regimes: The prevailing fire regime in white poplar's native habitats was not described in the available literature (2010). Fire regimes in white poplar's nonnative habitats are difficult to characterize. Widespread planting of white poplar in North America has made many vegetation types potential habitat for white poplar. While dense white poplar and white poplar hybrid stands could alter fire frequency or fire behavior in invaded habitats, their impact on natural fire regimes had not been studied as of 2010. See the Fire Regime Table for more information on the fire regimes in vegetation communities that may support white poplar or its hybrids.

FIRE MANAGEMENT CONSIDERATIONS:

Potential for postfire establishment and spread: Abundant postfire sprouting is suspected following fire in white poplar stands (Johnson 2010 personal communication [54]). In areas supporting white poplar together with bigtooth aspen, quaking aspen, and/or European aspen, hybrid seedlings may also occur. For more information on white poplar hybridization, see the earlier discussions in the Seed production, Seed dispersal, and Seedling establishment sections.

Preventing postfire establishment and spread: Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant seed into burned areas. General recommendations for preventing postfire establishment and spread of invasive plants 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 that may alter soil nutrient availability, such as those containing nitrogen and phosphorus
- Avoid areas dominated by high priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases
- Clean equipment and vehicles prior to entering burned areas
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- Monitor burned areas and areas of significant disturbance or traffic from management activity
- Detect weeds early and eradicate before vegetative spread and/or seed dispersal
- Eradicate small patches and contain or control large infestations within or adjacent to the burned area
- Reestablish 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: [3,8,37,113].

Use of prescribed fire as a control agent: Although detailed management guidelines for the use of fire to control white poplar and its hybrids are lacking, some weed control documents suggest that annual repeated fire may reduce sprout abundance and limit spread [16,97]. Solecki [97] reports that cutting may be necessary in dense white poplar stands to encourage enough herbaceous fine fuel growth to carry a fire. For "very large" clones, this process may require several years of cutting and burning-in from the stand edges before the clone center can be burned [97].

Altered fuel characteristics: Although dense white poplar and/or hybrid stands have the potential to alter fuel characteristics, fire behavior, and fire frequency in invaded habitats, altered fire regimes in invaded habitats had not been reported as of 2010. For more information, see Fuels and Fire regimes.

MANAGEMENT CONSIDERATIONS

SPECIES: Populus alba and hybrids

FEDERAL LEGAL STATUS:
None

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

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Few studies reported on the value of white poplar and white poplar hybrids to wildlife and livestock as of 2010. Use of white poplar was only noted in 2 studies. In Illinois, yellow-bellied sapsucker holes occurred in white poplar trees but were not abundant [38]. Based on observations made in western Massachusetts, white poplar was considered an attractive food source for eastern cottontails. However, only slight injury occurred from winter feeding by eastern cottontails [108]. It is likely that white poplar and its hybrids are utilized for food and cover by a wider variety of wildlife species than is indicated in the reviewed literature.

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

Cover value: It is likely that white poplar and hybrid stands provide shade and cover for wildlife and livestock. White poplar has been recommended to improve wildlife habitat [42]; however, its cover value was not evaluated in the literature as of 2010.

OTHER USES:
After discovering the high productivity and growth rates of naturally occurring *P. alba* × *P. grandidentata* stands in Iowa, widespread planting trials of these hybrids were recommended. Researchers compared the growth and profitability of *P. alba* × *P. grandidentata*, *P. deltoides* × *P. nigra*, and silver maple (*Acer saccharinum*) for pulp production on a variety of sites in Iowa. After 6 years of growth, *P. alba* × *P. grandidentata* produced the greatest height and DBH and had the highest survival rate (94%). Researchers reported that *P. alba* × *P. grandidentata* had the greatest potential for profit as a short-rotation, woody biomass crop for pulp and/or fiber production [36]. Researchers have also engineered an herbicide-resistant strain of *P. alba* × *P. grandidentata* [21]. This strain has been grown in field trials [74].

IMPACTS AND CONTROL:

Photo © Richard Old, XID Services, Inc., Bugwood.org

Impacts: Although details and documentation of white poplar's impacts on native vegetation and drainage structures are lacking, these impacts are commonly noted in floras, weed control handbooks, and landscape manuals.

Concern about the impacts of white poplar in wildlands varies, as do recommendations for prioritizing its control. White poplar is listed as a "significant threat" by many eastern weed organizations [61,98,109,118]. In a survey of Wisconsin's authorities on local flora, white poplar ranked 35th out of 66 nonnative invasive plants evaluated for their negative impacts on native plant communities [87]. It was ranked 36th in a list of 81 nonnative, invasive species impacting natural habitats of Canada [14]. Based on models using climatic tolerances, biological traits, and invasiveness in other wildlands, researchers predicted that white poplar was a very high threat for establishing and proliferating in Manitoba's Riding Mountain National Park [80]. White poplar was assigned high priority for removal from Point Pelee National Park, Ontario (Dunster 1990 cited in [123]).

White poplar was not considered a problematic species or a control priority in several other cases. It probably has less potential impact and receives lower priority for control in areas where it has not been widely planted and does not have the potential to hybridize with native aspens. In a survey answered by 35 Canadian botanists, most respondents indicated that white poplar was not a "problem species" and was invasive only locally. The survey was sent to botanists across Canada, but the regional distribution of respondents was not reported [123]. White poplar was relatively rare in Farmington, western Maine, and spread of clones was easily tracked back to areas where white poplar was planted [6]. Surveys of the flora in New London County, Connecticut, revealed that white poplar populations were uncommon and generally restricted to disturbed sites. Population sizes were stable [48].

Impacts from underground growth: The extensive white poplar root system has caused problems near houses or other urban developments. Several sources anecdotally report that white poplar roots can clog drains, sewers, and water channels [19,34,68]. In his manual of woody plants, Dirr [19] indicates that white poplar "becomes a nuisance and liability after a time". Dirr suggests that homeowners "avoid this pest". A pamphlet produced by England's Forestry Commission reports that white poplar can remove soil moisture rapidly during dry, hot days. In low-rainfall areas such as London and Essex, white poplar has caused rapid drying and shrinkage of clay soils, which can upset dwelling

foundations [26].

Impacts to associated vegetation: Impacts on associated vegetation may change as white poplar stands expand and age. Through prolific root sprouting, white poplar can develop dense stands, which can crowd and shade native vegetation and reduce species diversity [16,97,120]. As stands age, the breakage of brittle white poplar wood can damage nearby vegetation [73]. In the central Transvaal area of South Africa, where white poplar is nonnative, there is "marked correlation between the occurrence of naturalized and planted white poplar", but white poplar no longer occurs as isolated stands; instead, it occupies whole river reaches and has spread from the water's edge to far outside the riparian zone. White poplar has "out-compete(d)" and suppressed existing vegetation in its formation of "absolutely pure stands" [121].

Hybridization: White poplar hybridizes with native aspens. Researchers fear that this hybridization could change the native aspen gene pool or produce "vigorous" hybrids that could replace native aspens. Because of its hybridization ability, white poplar was rated as a high priority for control in Cape Breton Highlands National Park, Nova Scotia. Although current hybridization was not evaluated, white poplar populations occurred near quaking aspen and bigtooth aspen populations. Managers feared that hybridization could lead to the introgression of white poplar genes into the native aspen gene pool [103]. In southwestern Michigan, white poplar, native aspens, and their hybrids were evaluated. The impact of white poplar on the native aspen gene pools was considered low. As of the early 1980s, white poplar hybrid populations were clustered; recent hybridization, backcrossing, and extensive gene flow were not detected [101]. Hybrids were relatively disease and insect free [102].

Control: Because white poplar regenerates easily after top-kill (see Vegetative regeneration), it is difficult to control once established [13,88].

In all cases where invasive species are targeted for control, no matter what method is employed, the potential for other invasive species to fill their void must be considered [9]. Control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders [69].

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

Prevention: Although there has been widespread planting of white poplar in North America, eliminating future plantings could improve future control efforts and reduce the potential for contamination of the gene pool for native aspens. Restricting sale of white poplar could limit future use. Informing land owners of white poplar's objectionable traits, as was done by Appleton and others [2], may help to limit future plantings.

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 [69,93] and by monitoring several times each year [53]. Managing to maintain the integrity of the native plant community and mitigate the factors enhancing ecosystem invasibility is likely to be more effective than managing solely to control the invader [50].

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 [113]. See the Guide to noxious weed prevention practices [113] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

Cultural control: No information is available on this topic.

Physical or mechanical control: Vegetative regeneration and spread can be encouraged by cutting white poplar stems [73]. To be a viable control option, cutting will likely need to be frequent, repeated, and/or paired with another control method. Weed handbooks suggest controlling white poplar by repeated and frequent cutting [34,120]. In the tallgrass restoration handbook, white poplar spread is said to be controlled by girdling large trees and repeatedly cutting sprouts [97]. In a review, Czarapata [16] reports that white poplar stems with less than a 2-inch (5 cm) DBH may be controlled by cutting followed by herbicide treatments. Sprouting of girdled stems larger than 2 inches (5 cm)

in DBH may be limited by applying an herbicide to the wound [16].

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: [115,124] and the Weed control methods handbook [110] for background information and important considerations for developing and implementing biological control programs. For information on pests and diseases known to infect white poplar in the United States, see Spaulding [99].

Chemical control: Herbicides may be useful to control white poplar [34], but effectiveness may be improved if used in conjunction with other control methods [97].

Herbicides are 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 [11]. See the Weed control methods handbook [110] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

Integrated management: No information is available on this topic.

APPENDIX: FIRE REGIME TABLE

SPECIES: Populus alba and hybrids

The following table provides fire regime information for several natural communities that represent potential white poplar habitat. Follow the links in the table to documents that provide more detailed information on these fire regimes. Because of widespread planting of white poplar throughout the United States, many plant communities that could potentially be invaded by white poplar. See the Expanded Fire Regime Table for information on communities not listed below.

Fire regime information on vegetation communities in which white poplar may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [65], 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.

Pacific Northwest	California	Southwest	Great Basin	Northern and Central Rockies
Northern Great Plains	Great Lakes	Northeast	South-central US	Southern Appalachians
Southeast				

Pacific Northwest

- Northwest Grassland
- Northwest Shrubland
- Northwest Woodland
- Northwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of	Mean interval	Minimum interval	Maximum interval

		fires	(years)	(years)	(years)
Northwest Grassland					
Bluebunch wheatgrass	Replacement	47%	18	5	20
	Mixed	53%	16	5	20
Idaho fescue grasslands	Replacement	76%	40		
	Mixed	24%	125		
Northwest Shrubland					
Wyoming sagebrush steppe	Replacement	89%	92	30	120
	Mixed	11%	714	120	
Mountain big sagebrush (cool sagebrush)	Replacement	100%	20	10	40
Northwest Woodland					
Oregon white oak-ponderosa pine	Replacement	16%	125	100	300
	Mixed	2%	900	50	
	Surface or low	81%	25	5	30
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
Oregon white oak	Replacement	3%	275		
	Mixed	19%	50		
	Surface or low	78%	12.5		
Northwest Forested					
Dry ponderosa pine (mesic)	Replacement	5%	125		
	Mixed	13%	50		
	Surface or low	82%	8		

California

- California Grassland
- California Woodland
- California Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval	Minimum interval	Maximum interval

			(years)	(years)	(years)
California Grassland					
California grassland	Replacement	100%	2	1	3
Herbaceous wetland	Replacement	70%	15		
	Mixed	30%	35		
California Woodland					
California oak woodlands	Replacement	8%	120		
	Mixed	2%	500		
	Surface or low	91%	10		
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
California Forested					
Aspen with conifer	Replacement	24%	155	50	300
	Mixed	15%	240		
	Surface or low	61%	60		
Jeffrey pine	Replacement	9%	250		
	Mixed	17%	130		
	Surface or low	74%	30		

Southwest

- Southwest Grassland
- Southwest Shrubland
- Southwest Woodland
- Southwest Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southwest Grassland					
Desert grassland with shrubs and trees	Replacement	85%	12		
	Mixed	15%	70		

Shortgrass prairie with trees	Replacement	80%	15	2	35
	Mixed	20%	60		
Plains mesa grassland with shrubs or trees	Replacement	76%	20		
	Mixed	24%	65		
Montane and subalpine grasslands with shrubs or trees	Replacement	30%	70	10	100
	Surface or low	70%	30		
Southwest Shrubland					
Southwestern shrub steppe with trees	Replacement	52%	17	10	25
	Mixed	22%	40	25	50
	Surface or low	25%	35	25	100
Southwest Woodland					
Ponderosa pine/grassland (Southwest)	Replacement	3%	300		
	Surface or low	97%	10		
Southwest Forested					
Riparian deciduous woodland	Replacement	50%	110	15	200
	Mixed	20%	275	25	
	Surface or low	30%	180	10	
Southwest mixed conifer (warm, dry with aspen)	Replacement	7%	300		
	Mixed	13%	150	80	200
	Surface or low	80%	25	2	70
Southwest mixed conifer (cool, moist with aspen)	Replacement	29%	200	80	200
	Mixed	35%	165	35	
	Surface or low	36%	160	10	
Aspen with spruce-fir	Replacement	38%	75	40	90
	Mixed	38%	75	40	
	Surface or low	23%	125	30	250
Stable aspen without conifers	Replacement	81%	150	50	300
	Surface or low	19%	650	600	>1,000

Great Basin

- Great Basin Shrubland
- Great Basin Woodland

- Great Basin 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 Basin Shrubland					
Wyoming big sagebrush semidesert with trees	Replacement	84%	137	30	200
	Mixed	11%	≥1,000	20	>1,000
	Surface or low	5%	>1,000	20	>1,000
Mountain shrubland with trees	Replacement	22%	105	100	200
	Mixed	78%	29	25	100
Great Basin Woodland					
Ponderosa pine	Replacement	5%	200		
	Mixed	17%	60		
	Surface or low	78%	13		
Great Basin Forested					
Aspen with conifer (low to midelevation)	Replacement	53%	61	20	
	Mixed	24%	137	10	
	Surface or low	23%	143	10	
Stable aspen-cottonwood, no conifers	Replacement	31%	96	50	300
	Surface or low	69%	44	20	60
Aspen with spruce-fir	Replacement	38%	75	40	90
	Mixed	38%	75	40	
	Surface or low	23%	125	30	250
Stable aspen without conifers	Replacement	81%	150	50	300
	Surface or low	19%	650	600	>1,000

Northern and Central Rockies

- Northern and Central Rockies Grassland
- Northern and Central Rockies Shrubland
- Northern and Central Rockies Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of	Mean interval	Minimum interval	Maximum interval

		fires	(years)	(years)	(years)
Northern and Central Rockies Grassland					
Northern prairie grassland	Replacement	55%	22	2	40
	Mixed	45%	27	10	50
Mountain grassland	Replacement	60%	20	10	
	Mixed	40%	30		
Northern and Central Rockies Shrubland					
Riparian (Wyoming)	Mixed	100%	100	25	500
Northern and Central Rockies Forested					
Ponderosa pine (Northern and Central Rockies)	Replacement	4%	300	100	≥1,000
	Mixed	19%	60	50	200
	Surface or low	77%	15	3	30

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					
Northern mixed-grass prairie	Replacement	67%	15	8	25
	Mixed	33%	30	15	35
Southern mixed-grass prairie	Replacement	100%	9	1	10
Central tallgrass prairie	Replacement	75%	5	3	5
	Mixed	11%	34	1	100
	Surface or low	13%	28	1	50
Northern tallgrass prairie	Replacement	90%	6.5	1	25
	Mixed	9%	63		
	Surface or low	2%	303		
	Replacement	96%	4	1	10
	Mixed	1%	277		

Southern tallgrass prairie (East)					
	Surface or low	3%	135		
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		
Northern Great Plains wooded draws and ravines	Replacement	38%	45	30	100
	Mixed	18%	94		
	Surface or low	43%	40	10	
Great Plains floodplain	Replacement	100%	500		

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					
Great Lakes pine barrens	Replacement	8%	41	10	80
	Mixed	9%	36	10	80
	Surface or low	83%	4	1	20
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		
Great Lakes floodplain forest	Mixed	7%	833		
	Surface or low	93%	61		
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		
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
Northeast Forested					
	Replacement	39%	≥1,000		

Northern hardwoods (Northeast)	Mixed	61%	650		
Beech-maple	Replacement	100%	>1,000		

South-central US

- South-central US Grassland
- South-central US Shrubland
- 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					
Bluestem-sacahuista	Replacement	70%	3.6	1	
	Mixed	30%	7.7	2	
Desert grassland	Replacement	82%	8		
	Mixed	18%	37		
Southern shortgrass or mixed-grass prairie	Replacement	100%	8	1	10
Southern tallgrass prairie	Replacement	91%	5		
	Mixed	9%	50		
Oak savanna	Replacement	3%	100	5	110
	Mixed	5%	60	5	250
	Surface or low	93%	3	1	4
South-central US Shrubland					
Southwestern shrub steppe	Replacement	76%	12		
	Mixed	24%	37		
South-central US Woodland					
Oak-hickory savanna	Replacement	1%	227		
	Surface or low	99%	3.2		
Oak woodland-shrubland-grassland mosaic	Replacement	11%	50		
	Mixed	56%	10		

	Surface or low	33%	17		
Interior Highlands oak-hickory-pine	Replacement	3%	150	100	300
	Surface or low	97%	4	2	10
South-central US Forested					
West Gulf Coastal plain pine (uplands and flatwoods)	Replacement	4%	100	50	200
	Mixed	4%	100	50	
	Surface or low	93%	4	4	10
West Gulf Coastal Plain pine-hardwood woodland or forest upland	Replacement	3%	100	20	200
	Mixed	3%	100	25	
	Surface or low	94%	3	3	5
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					
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

Southeast

- Southeast Grassland
- Southeast Woodland
- 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 Grassland					
Southeast Gulf Coastal Plain Blackland prairie and woodland	Replacement	22%	7		
	Mixed	78%	2.2		
Southeast Woodland					
Longleaf pine (mesic uplands)	Replacement	3%	110	40	200
	Surface or low	97%	3	1	5
Atlantic wet pine savanna	Replacement	4%	100		
	Mixed	2%	175		
	Surface or low	94%	4		
Southeast Forested					
Coastal Plain pine-oak-hickory	Replacement	4%	200		
	Mixed	7%	100		
	Surface or low	89%	8		
Maritime forest	Replacement	18%	40		500
	Mixed	2%	310	100	500
	Surface or				

	low	80%	9	3	50
Loess bluff and plain forest	Replacement	7%	476		
	Mixed	9%	385		
	Surface or low	85%	39		
Southern floodplain	Replacement	7%	900		
	Surface or low	93%	63		

*Fire Severities—
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 [44,64].

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